The Finnish Environment

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ENVIRONMENTAL PROTECTION

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Evaluation of environmental cross-media and economic aspects in industry – Finnish BAT expert case study

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HELSINKI 2002

FINNISH ENVIRONMENT INSTITUTE

ISBN 952-11-1042-2
ISBN 952-11-1043-0 (PDF)
ISSN 1238-7312

Cover photo: Tero Pajukallio
Oy Edita Ab
Taitto: Diaidea Oy
Helsinki 2002 Helsingfors

Preface

The Commission of the European Communities has set up information exchange on economic and cross-media aspects (ECM) under the Directive on Integrated Pollution Prevention and Control (IPPC, 96/61/EC). The work is co-ordinated and run by the European IPPC Bureau in Seville, Spain. A technical working group (TWG), consisting of representatives from the Member States and industrial organisations, prepares a draft reference document for the discussion at the Information Exchange Forum (IEF). Finally the Commission shall adopt the reference document. The TWG for cross-media and economic aspects commenced its work in May 2000. The work aims at supporting both sector level (vertical) EU best available techniques reference document (BREF) preparation as well as permitting procedure of IPPC installations on local level.

The objective of this study is to give support to the Finnish contribution in the preparation of the EU reference document on economic and cross-media aspects (ECM REF). Moreover it will provide background information for integrated environmental permitting in Finland. Different methods and approaches for economic and cross-media evaluation are identified, discussed and demonstrated with practical examples from pulp and paper production as well as energy production. A particular emphasis is placed on practical application in permitting context. The inputs of the Member States and industrial organisations for the ECM work on EU level were taken into account in the preparation of this document.

This report consists of contributions from Finnish Environment Institute (Chapter 5 and parts of Chapters 1-3, Appendix 1), Government Institute for Economic Research (in Chapters 3, 4 and 6, Appendix 2) and the work that has been otherwise completed and coordinated by JP Management Consulting. In the case study section also information of Finnish Energy Industries Federation (Finergy) and Fortum Ltd has been used.

Several cross-media conflicts, proceeding from simpler to more complicated ones, are highlighted with possible methods to deal with the problems. The applicability of the methodologies is assessed and discussed. The dimensions of trade-offs and possible conflicts cover air, water, soil, energy, time, product quality and costs. The methods are targeted for the local level, whereas their use on EU level is not endorsed due to the significant variations in natural, anthropogenic and technological environment between facilities in different localities across Europe. Among economic methodology methods related to investment appraisal (e.g. Net Present Value) and cost allocation, (e.g. Activity Based Costing) are introduced. In contrast to environmental evaluation, the costing methodology is considered applicable on both EU level and local permitting level.

The study team consisted of the following experts: Petri Vasara, Pia Nilsson, Laura Peuhkuri, Katja Bergroth, Kari Harmaa (Jaakko Pöyry Consulting Oy); Kimmo Silvo, Seppo Ruonala, Matti Melanen, Irina Hakala, Timo Jouttijärvi, Jorma Leivonen (Finnish Environment Institute); Jukka Leskelä (Finergy); Esa-Jukka Käär (Finnish Forest Industries Federation); Adriaan Perrels (Government Institute for Economic Research); Leena Nurmento (Fortum Ltd) and Mervi Salminen (Ministry of Trade and Industry).

The work has been guided and commented by the national branch group with the following members: Kimmo Silvo (chair, Finnish Environment Institute), Timo Parkkinen (Ministry of the Environment), Mervi Salminen (Ministry of Trade and Industry), Heikki Sourama (Ministry of Finance), Tapio Kovanen (Western Finland Environmental Permit Agency), Pirjo-Liisa Nurmela (Vaasa Administrative Court), Päivi Vilenius (Häme Regional Environment Centre), Ann-Mari Häkkinen (Western Finland Regional Environment Centre), Riitta Larnimaa (Confederation of Finnish Industry and Employers), Esa-Jukka Käär (Finnish Forest Industries Federation), Adriaan Perrels (Government Institute for Economic Research), Heikki Niininen (Finergy), Seppo Ruonala (Finnish Environment Institute), Jorma Leivonen (Finnish Environment Institute), Irina Hakala (Finnish Environment Institute) and Timo Jouttijärvi (Finnish Environment Institute). Funding for the work was provided by Finnish Environment Institute, Finnish Energy Industries Federation (Finergy) and Finnish Forest Industries Federation.

Contents

The cross-media problem: a general introduction

The main agents for cross-media control have perhaps been three regulations/directives/proposals: the UK integrated pollution control (IPC), the US EPA Cluster Rules and the EU integrated pollution prevention and control (IPPC). All them acknowledge the fact that environmental media (air, water and soil) are interconnected and that an improvement in one may cause deterioration in another.

One of the most common areas of the cross-media problems is the shift of pollutants from air to water or from water to air. The eternal loop spawned by two examples of the past US environmental legislation can be used as an illustration of the importance of integrated approach and air ÷ water transfer: for the chemical pulping process, the 1987 CWA (Clean Water Act) could be partially satisfied by the vaporisation of chemicals out of waste water (Figure 1). This led to an atmospheric pollution problem. In their turn, the 1990 Clean Air Act Amendments (CAAA) could be partially satisfied by the inverse operation: condensing atmospheric pollutants, with a resultant water pollution problem. Thus, an eternal loop had been construed. This does not imply that the U.S. is a failure in this respect. It is simply an example of which there are many in Europe also.

However, already in the late eighteenth century, a French chemist Antoine Lavoisier (1743–1794) found that mass is neither created nor destroyed in a reaction. This discovery of his, the law of conservation of mass, was the basis for the further developments in chemistry and physics.

$$\text{mass}_{in} = \text{mass}_{out}$$

So: what we are dealing with in cross-media are the laws of nature. Matter taken from, e.g., the air does not disappear. As the IPPC Directive aims to forbid moving problems from one area to another, we have to find ways to obey the laws of nature and the Directive.

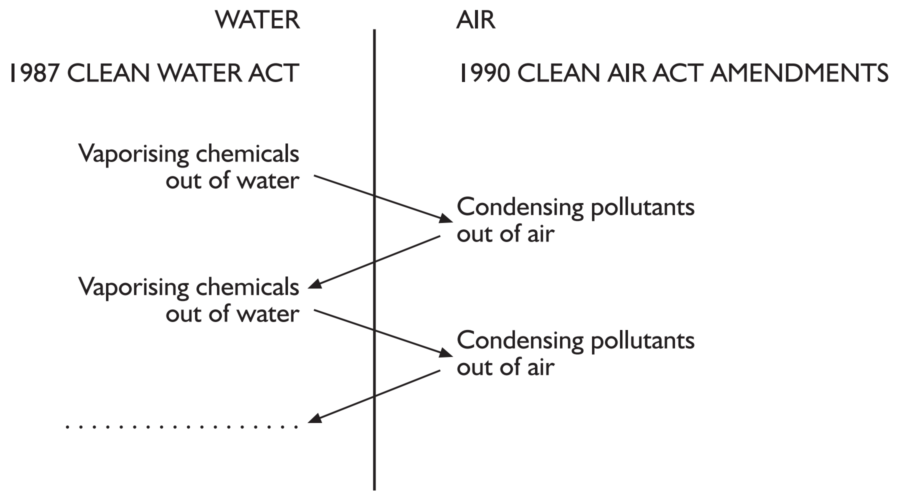

Figure 1. Eternal loop from the past.

2 Goal definition and scope

2.1 Definition

One of the main purposes of the IPPC Directive is to achieve a high level of environmental protection as a whole against the pressures arising from the activity of an industrial installation. The integrated and holistic viewpoint of the Directive covers all media – air, water and soil, energy efficiency and use of raw materials – whereas the scope does not extend to the manufacture and transportation of raw materials and transportation, use or disposal of products. Hence a full life cycle assessment is not directly applicable to the cross-media assessment in accordance with the IPPC Directive. Economic viability, cost-effectiveness and consideration of costs and benefits are part of the notion of Best Available Techniques (BAT) forming the basis of technical measures required.

While the technological and economic performance and viability form the basis of the BAT evaluation (bottom up), the IPPC Directive requires that at the same time the emissions from an installation must not jeopardise a certain minimum level of environmental quality stipulated by environmental quality standards (top down). This principle of combined approach is reinforced in Water Framework Directive (2000/60/EC). It is worth noting that the objectives set for the status of the environment in the vicinity of a pollution source in most cases go clearly beyond the minimum requirements marked by the environmental quality standards. In local permitting, the environmental harms and benefits must be evaluated to a large extent against the specific conditions and goals of the particular location and the framework set in the legislation.

Cross-media deliberation can be regarded as a pursuit of the best balance between emissions into air, water and soil as well as high energy-efficiency and prudent use of raw materials achieving a high level of environmental protection as a whole. In the integrated assessment of different types of environmental and health impacts, e.g., global warming, ozone depletion, acidification, tropospheric ozone formation, eutrophication, ecotoxicity, biodiversity, human health and nuisances trade-offs need to be determined. Trade-off judgements involve transparent arguments, in support of a certain balance between different types of environmental and health aspects. It has to be recognised that cross-media and trade-off assessments inevitably involve value judgements. One of the features of value judgements is that they tend to change over time. Hence there are no single calculation rules and methodology available that could produce the objective and correct solution to the cross-media problems.

The cross-media assessment is complicated by the intrinsic complexity of raw materials, processes, mass flows and structure of facilities. Typical examples of cross-media issues include waste generation and energy consumption against emission abatement or air emission reduction against increase in wastewater emission and energy consumption. The number and complexity of cross-media aspects varies significantly between different sectors and installations. If there are significant cross-media conflicts involved, a preferably quantitative analysis on the local level is needed before a balanced decision can be made. As an example, in modern Finnish pulp plants it was found out that issues related to efficient use of energy and control of disturbances were very significant from the point of view of achieving a good cross-media balance.

2.2 Scope

The goal of this study is to:

- Identify problems and trade-off issues related to the integrated management of emissions and other impact factors,
- Introduce methods to deal with cross-media issues,
- Illustrate possibilities for the integrated assessment of environmental harms and benefits in local permitting procedure; and
- Depict data on costs and costing methodology of environmental protection measures for industrial activities.

The key questions of the study are:

1) What are the typical trade-off issues in environmental permitting of an industrial installation?
2) How could we deal with environmental harms and benefits as well as economic aspects in environmental permitting?

Environmental and economic methods are combined for four cases from pulp and paper production and energy production. The cases illustrate on plant level cross-media conflicts in real situations and have a varying degree of complexity.

Costing methodology in this study is mainly targeted for internal environmental costs whereas external environmental cost methods are only briefly described. Difficult areas of costing methodologies, uncertainties involved and difficulties to acquire adequate data are highlighted.

2.3 Purpose of the document

The purpose of the document is to

- Offer practical help in a variety of different cases – yet with a strong methodological background
- Be readable to authorities and enterprises alike, linking methodologies to practical applications
- Present a practical view of relevant decision making (e.g., investments, permits) and ways to improve communication

Hence, it is not a comprehensive handbook for authorities and/or enterprises.

2.4 Plot

The plot described above can be summarised as in Figure 2 below.

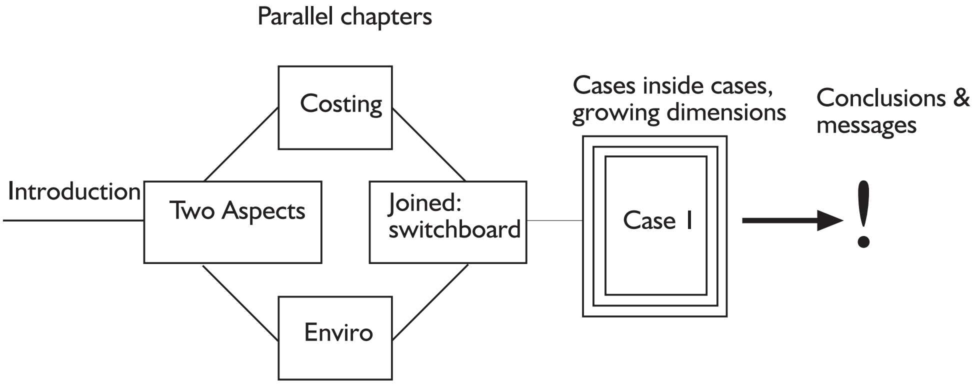

Figure 2. The plot.

Methodologies: differences and overlaps

3

3.1 Introduction

In this report, there are two parallel chapters (4 and 5), which then join in Chapter 6. The key point is the dividing line between direct cost and indirect cost. One way to express it is to portray it as a moving line drawn in the sand (Figure 3).

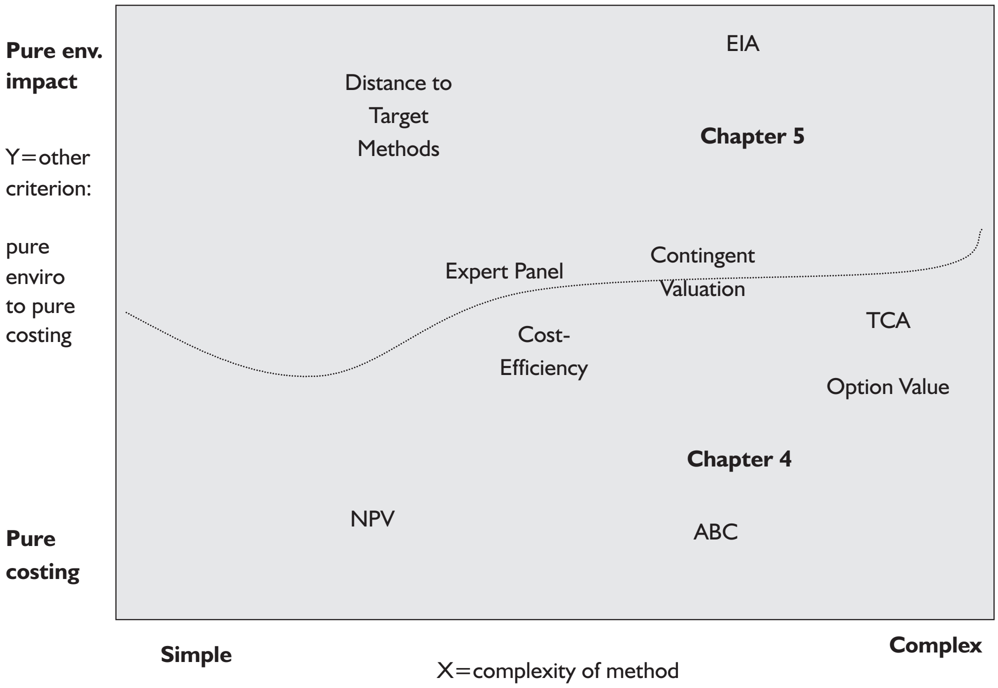

Figure 3. Moving line drawn in the sand: costing and environmental methods.

The overlap problem

Many methods in themselves attempt to combine both environmental and economic aspects and direct and indirect costs. Thus these factors often overlap and the difference between environmental and economic (costing) impact is a fine line. In order to make the classification easier to understand, we have developed the method CALORIE that includes e.g. the diagram described in Figure 4. For further information, see Olin *et al.* (2000), Vasara *et al.* (2000).

One of the main reasons for the overlap problem is the difficulty to separate environmental investments from other process investments. To be a total strategic success, an investment should be efficient

- Financially,
- Technologically,
- Environmentally.

The Good, the Bad and the Ugly: A good investment is all of these. A bad investment fails at least in one respect. An ugly investment fails environmentally.

There also has to be some means of classifying investments into the purely financial, the purely environmental, and the enviro-economic. The ”Bull’s Eye”, in Figure 4, can be used as the symbol and visualisation. In the outer-most rim, we have the purely financial investments, in the central part, the purely environmental investments, and in the grey zone in-between, the enviro-economic combination. It is in the grey zone where most investments lie and where win-win (and loss-loss) cases can be found.

The complexity problem

Environmental issues are unfortunately seldom simple. Complexity has an influence on data needs. The methods used have to be chosen and tailored for the purpose of the problem and take into account its complexity. The diagram in Figure 3 shows the methods classified according to their complexity.

3.2 Methods

Costing methods:

1. Investment Appraisal – Total Cost Assessment (TCA), Net Present Value (NPV), Annualised Capital Charges, Option Value and Cost-Effectiveness Analysis
2. Cost allocation – Activity Based Costing (ABC).

Environmental impact analysis methods

The difference between costing and environmental impact methods is not just a line drawn in the sand – it is a moving line drawn in the sand, shifting as methods are developed further and depending on the area where the methods are applied.

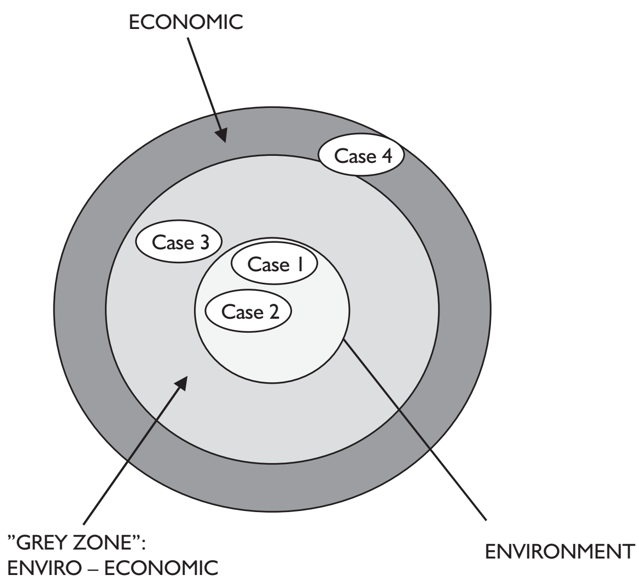

Figure 4. The bull’s eye of investments.

3.3 Decision-making

One goal of the study is also to crystallise decision-making schemes and look at possibilities to promote communication. To this end, the decision-making surrounding, e.g., environmental permits and investments is first presented concisely. Then, conclusions are drawn.

3.3.1 Permitting procedures

The main purpose of environmental permitting is to safeguard public interests, such as the environment, and determine judicial framework for private economic activities. In Finland the permit usually contains limit values for emissions based on best available techniques, monitoring requirements and various obligations e.g. for further research or restoration of the environment. Usually there is a review of the permit conditions every 5–10 years. An important aspect of the permitting procedure is that the different operators must be treated objectively and equally. Hence the contents of the environmental permit cannot be designed only based on the optimisation of the notion of BAT. However the BAT principle clearly contributes to the development of an effective and efficient permitting system.

On the EU BAT level, consideration can be restricted to input and emission levels including cross-media and cost aspects because that is sufficient for the comparison of the applied techniques. A particular difficulty often arises in determining a reasonable balance between emissions causing local impacts (e.g., eutrophication of receiving waters) and emissions contributing to regional and global environmental problems (e.g., global warming, troposheric ozone formation).

In local evaluation of impacts, dispersion, exposure and effects must be scrutinised in most cases. Often there are major difficulties in determining the full impact pathway of emissions: the quantity of emission, transportation, transformation and degradation of harmful substances, exposure, the actual impact and finally its significance. Complexity of the subject increases moving from emissions to impacts. In permitting also the health impacts and effects on amenities need to be looked into in connection with the environmental effects.

The environmental permitting process involves several stages in which the legal rights of different parties must be secured. The main phases of an environmental permitting process in Finland are shown in Figure 5. One of the corner stones of the process is that the individuals and groups concerned are informed about the permit application and decision and they have an opportunity to express their opinion about the undertaking and appeal against the decision. In permit deliberation, all the pieces of primary and secondary legislation, often based on EU Directives, with their particular requirements, obligations, compensations, bans, restrictions, emission limit values and environmental quality standards must be taken into consideration and respected. The BAT and cross-media evaluation takes place within that legal framework. Hence, in practice, there is a restricted scope within which cross-media evaluation and trade-off decisions can be made.

3.3.2 Investment planning

In this section, an investment is defined and the decision-making process of the investment is described. It is useful to start by making a distinction between investments into real and financial assets. When making a real investment, a company spends its money on some tangible assets such as land, buildings or machinery. A financial investment is spending money on a contract written on paper such

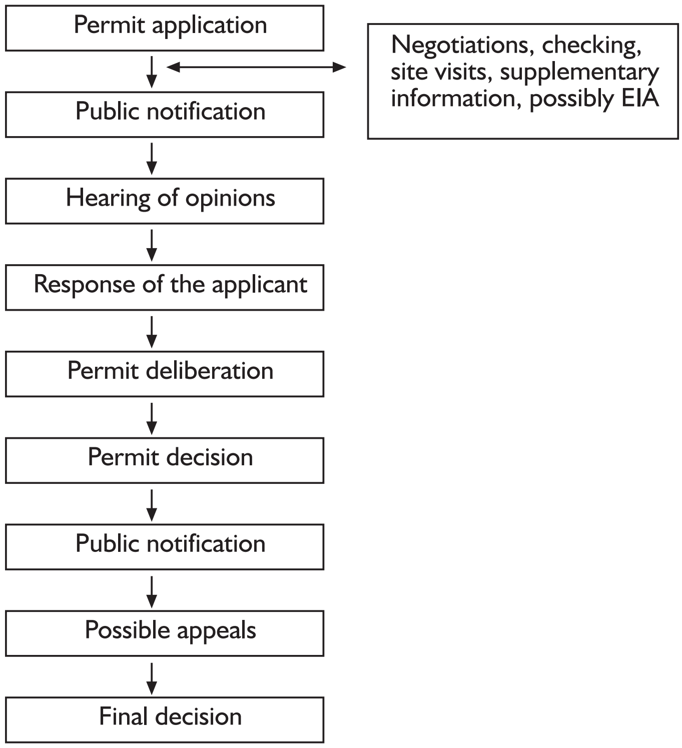

Figure 5. The main phases of the environmental permitting in Finland.

as common stocks and bonds. An investment is usually made in order to receive some financial returns whether directly monetary or achieved via improved production processes. In the case of an environmental investment, legislation, or anticipation of it, may have an effect on the companies' investment decisions.

Decision-making sequence

The decision-making process related to undertaking investments is an iterative process (Figure 6) that can last from a few months to several years depending on the size and nature of the investment. A general investment planning sequence includes a preliminary planning – or strategic – phase in which various analyses are undertaken in order to determine whether an investment is worth making at all. After this phase the project is 1) approved for further investigation, 2) returned for re-examination or 3) rejected. If the project is approved we move to the next phase that is analysis of the basic engineering and making preliminary plans on project finance. In the last phase, the actual implementation starts; technical details are polished and construction starts, final finance negotiations are held and machinery suppliers are decided upon.

The company undertaking an investment is influenced during its planning process by: legal requirements, market requirements and business requirements. Some or all of these may carry an environmental protection aspect. Figure 7 illustrates how the company is surrounded by the different requirements that are simultaneously interconnected. For instance, business activities are constrained partly by legislation and partly by consumer demand.

All of the requirements are interconnected, as shown by the big circle surrounding the company. Simultaneously each of the requirements puts stress on the company, as shown by the arrows.

Private versus public economy

Public authorities define the objectives of environmental policy. Hence it is also useful to mention some differences between the private sector (e.g., company level) and the public sector (e.g., national, EU level) economic point of view. Private companies' primary concerns are often being cost-efficient, creating value for shareholders, and achieving and maintaining a good competitive position. State economic authorities are mostly interested in such matters as economic growth (measured by, e.g., GDP), high level of employment and smoothening business cycles.

Hence there is always a risk that a company may not find an investment worthy to make although it would be socially desirable. On the other hand, a company may make an investment that is not desirable from a national economic point of view even though the private company would consider it profitable. Market failure is a situation where prices do not lead to efficient allocation of resources. This may be because the prices are skewed (due to lack of competition/e.g., mo-

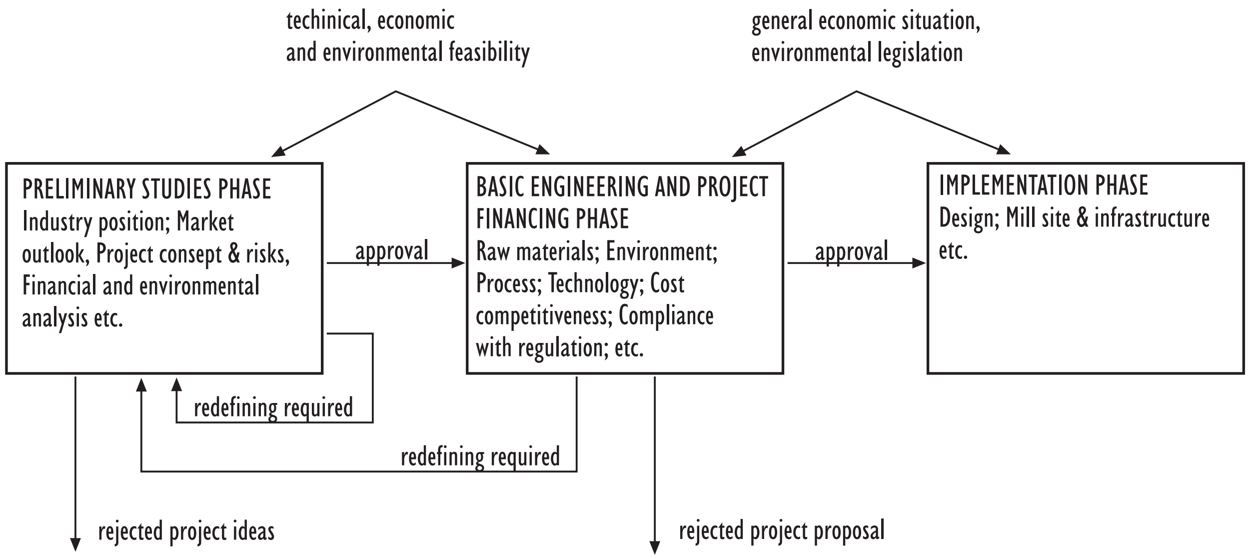

Figure 6. The iterative process of an investment project.

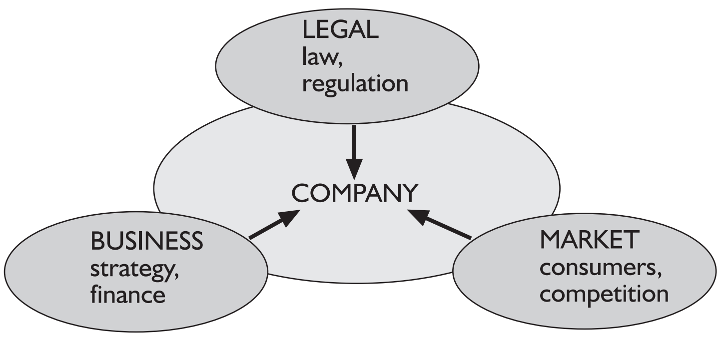

Figure 7. Requirements on the decision-making of a company.

nopoly, undervalued product/e.g., education) or they do not exist (as is the case with many environmental assets).

Pollution is a classic example of a negative external effect (externalities may also be positive). If the company does not, for one reason or another, clean up pollution caused by it, or if the source of pollution cannot be explicitly allocated, there is a problem. The polluting company will not have an incentive to invest in clean technology if it does not receive any benefits from it. From a national point of view, however, cleaning up the pollution before it is emitted would often cost less than cleaning it afterwards. The relationships of public goods, environmental policies and environmental effects in markets are further discussed in Appendix II. Hence public interventions, such as permitting or economic policy instruments, are necessary.

3.4 Positioning of policy and the use of BAT

The obligation to have a permit for operating an industrial installation, which emits environmentally harmful substances, is the result of preceding steps in environmental policy making. These preceding steps have not been taken in isolation; instead the criteria for granting a permit are usually the result of negotiations between various stakeholders. BAT cross-media benchmarks do not only take environmental limits into account but also economic feasibility. The balance between economic feasibility and environmental requirements can be achieved in many ways. Apart from varying emission limits as such, aspects such as subsidy schemes, the length of the transition period toward compliance, and R&D programmes for better and/or cheaper abatement technologies can all be part of the solution.

Environmental policy formulation does not stand alone. In the case of Finland one can point for example to the interaction with economic sector policies and with spatial policies (e.g., managing interregional differences in an equitable way). The same or similar observations are valid for virtually all EU member countries.

The use of BAT benchmarks in the framework of a permitting procedure should be seen as steps in a two tier bargaining process. At a more strategic level, there is the setting of standards and norms together constituting a BAT for a particular production process – emission combination and/or sector – emission combination. Once in X years these benchmarks will be revised. The revision may be partly automatic, partly negotiated. Secondly, at the practical level there is the application of the BAT benchmark in a concrete permit request. The essentials of this are indicated in Figure 8.

One has to realise that both the strategic BAT specification and its case wise application in project appraisals are in fact bargaining situations. The company makes trade-offs, on the one hand regarding its position in the market and on the other hand regarding it's positioning towards the BAT based permitting. Also the public authority is in a bargaining (trade-off) situation, since it aims on the one hand at the achievement of environmental policy goals, but on the other hand has to take account of other policy goals such as safeguarding welfare levels and interregional social-economic equity.

The strategic level trade-off processes take place in the policy formulation and BAT specification phase (e.g., with the aid of the present study). In the Finnish system of permit granting little leeway is left, as the procedures and response options are pre-specified. Yet, in principle, and indeed in practice in various EU member countries trade-off at the practical level can happen for example by allowing a certain transition time or by granting subsidies in exchange for keeping up high environmental standards. A permit granting authority could also agree to issue a permit not for one installation, but for an entire industrial complex or area

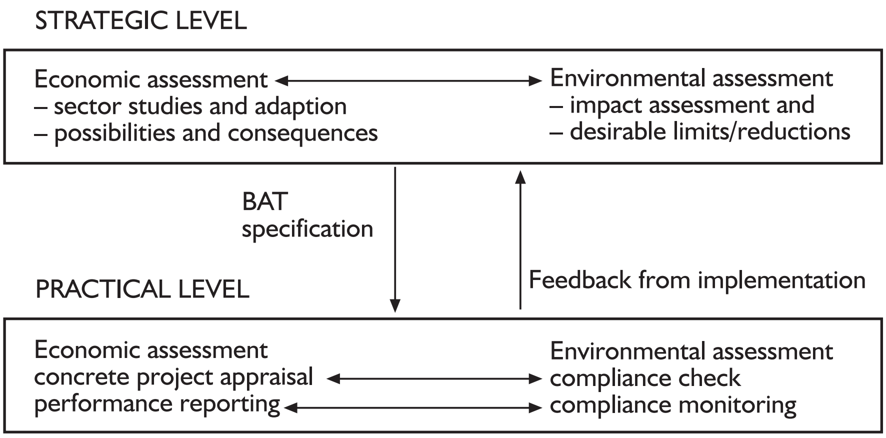

Figure 8. BAT specification and use at strategic and practical policy levels.

(the so-called 'bubble-concept'). This allows for more flexibility, while the total amount of local emissions is still reduced to target levels.

It might be useful to provide workable benchmark concepts and examples as well as project assessment guidance in which the benchmarks can be used as much as possible according to standardised and at least tractable procedures. The benefits of providing guidelines, standard indicators and benchmarks are in the cost reducing effect of moving gradually towards more precision in the assessment. In this way the making of trade-offs is facilitated and the transaction costs (i.e., the assessment and negotiation cost) are lowered.

4 Economics of environmental investments

4.1 Introduction

This chapter gives a short presentation of methods that could be applied to evaluating the economic feasibility and efficiency of investments. For each of these methods, the linkage to real-life investments is brought out. The individual methods cover different aspects of making an investment by a company. In various combinations these methods and concepts contribute to the methodology chosen for a case but certainly they do not make up a universally applicable truth. Some internal management tasks of a company are shown in Figure 9. The methods and concepts introduced in this chapter have, in this figure, been related to the appropriate tasks.

Environmental investments

Environmental regulation obliges industries to lower their environmental load, which implies that most of them will have to invest in new technology. This chapter introduces some costing frameworks, methods and concepts applicable to assessment of environmental investments. Environmental investment analysis is closely related to environmental accounting. Traditionally an investment is expected to produce economic returns to the company but a pure environmental investment lacks such requirements. On the national or EU level the adoption and de-

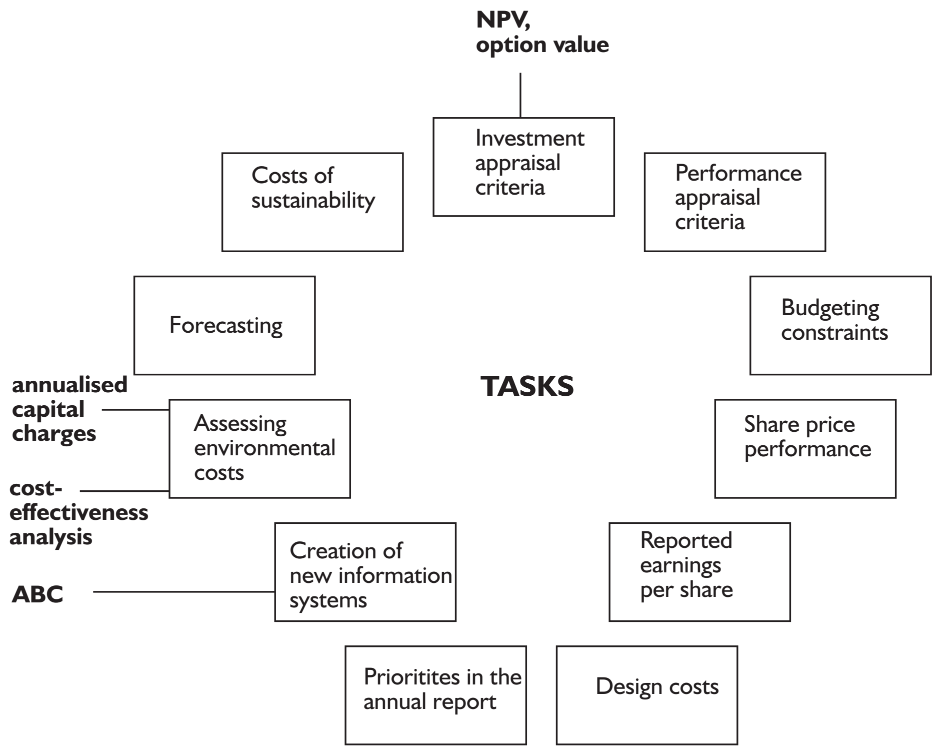

Figure 9. Company tasks and useful methods.

velopment of environmental technology depends on demand, R & D efforts and relative prices as well as on policy incentives.

As mentioned in Chapter 3, it should be kept in mind that even the notion of an "environmental investment" is not clear-cut. Investments in new machinery and technological solutions may be accompanied with a decrease in environmental load, but should this kind of investments be called "environmental"? In real life it is actually often hard to make a clear distinction between an economic and an environmental investment. Investments that fall between these categories are common, e.g., an environmental investment which at the same time saves energy hence also money. This ambiguity poses a challenge to the determination and accounting of investment costs. The environmental investments are starting to involve sufficiently high costs that they should no longer be allocated into general overhead as has been done previously.

Cost appraisal layers and policy connections

The assessment of the cost of environmental compliance runs through several phases. Since investment appraisal as such incurs cost[1], there is generally first a fairly superficial assessment to get a general idea of the feasibility. Subsequently, if feasibility is not rejected, more detailed cost assessment can be applied. This process is summarised in Figure 10. The picture also takes into account that the cost perception and effects depend on the company and public policy context, as has been explained briefly in Chapter 3. Higher cost needs not always be problematic, while the specification of the BAT in the environmental regulation should be regarded as part of the process and not in isolation.

The benefits of providing guidelines, standard indicators and benchmarks are in the cost reducing effect of moving only gradually towards more precision in the assessment. In the beginning standard indicators and procedures can be used, lat-

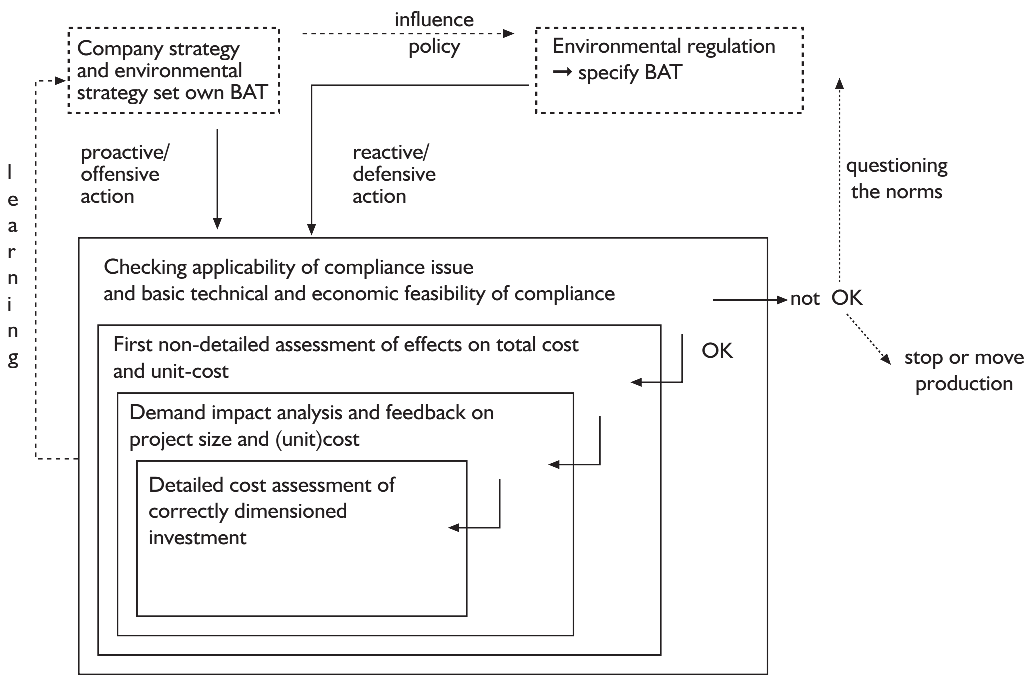

Figure 10. Layers in investment cost appraisal and its public and company policy context.

1. It is not only the cost of carrying out an appraisal, but the time and attention required from the management has an opportunity cost, this counts especially in medium-sized and small firms.

er on they can be more and more replaced by case specific data. The extent of replacement depends on the required level of precision and the cost of precise data. It generally holds that the larger the company and/or the more experience it has accumulated in the policy area the more data are readily available (e.g., in company databases, or energy agency help desks).

In the following sections first the cost concepts will be explained. Subsequently we explain why and how to take care of demand effects.

4.2 Methods and concepts

This chapter only considers the costing of internal environmental measures of a company. From a societal point of view the expenses incurred from these investments may be called "private costs". Life cycle costing and valuation of environmental harms and benefits involve costs to external parties, and are thus beyond the scope of this chapter.

This subchapter is divided into two parts according to the role individual methods and frameworks play in investment sequence:

1. Investment Appraisal – Total Cost Assessment (TCA) complemented with Net Present Value (NPV), Annualised Capital Charges and Option value are introduced. Cost-Effectiveness Analysis is also briefly described.
2. Cost allocation – The accounting method Activity Based Costing (ABC) is described.

At the end of each section there is a very brief summary of examples on how the individual method can be used by a company.

4.2.1 Investment appraisal

Total Cost Assessment (TCA) is a general investment appraisal framework. The basic idea is to compare investment alternatives. TCA can be defined as a long-term, comprehensive financial analysis of the full range of internal costs and savings of an investment. TCA is a broadly used term for any traditional investment accounting hence "traditional cost assessment" might be a better term to use. This framework focuses on the direct and visible costs. The cost is allocated in the accounting system into overhead costs and it is then divided equally between the different parts of, e.g., the production unit.

Incorporating environmental costs into "traditional" investment appraisal poses a major challenge. Schaltegger et al. (1996) provide some suggestions for how to overcome the problems associated with environmental costing by expanding the traditional TCA framework:

- Cost inventory may be expanded to include in addition to direct costs also indirect costs (regulatory compliance fees, training, deterioration, etc.), potential liabilities (contingent liabilities, potential fees, fines, taxes, etc.) and finally also less tangible costs such as company image. The added categories contain many elements that will be hard to measure but nevertheless they may contribute significantly to the profitability of an investment.
- Environmental costs can be better incorporated into investment appraisals by extending the time horizon and using long-term financial indicators (NPV, option value).
- Comments about cost allocation will be explained in Section 4.2.2.

Net Present Value (NPV) is the value of the investment calculated as a sum of discounted future payments minus the investment's current cost. Internal Rate of

Return is the discount rate at which NPV would equal zero. The investment project is required to achieve a non-negative NPV in order to be implemented.

$$NPV = -\left(\text{cost of the investment}\right) + \sum_{i=1}^{n}\left(\frac{\text{income}_i}{\left(1+r\right)^i}\right)$$

where r is the discount rate used.

The NPV method takes into account "the time value of money". Cash payments/ incomes are included regardless of the time when they have been paid/received. However, the method is highly dependent on the discount rate used. For instance a 1 %-unit change in the discount rate may already distort the results. Only cash flows are included (e.g., depreciation is ignored). Allocation is not taken into account.

Possible uses: NPV is commonly used for evaluating the economic feasibility of an investment: if NPV is positive – go ahead, if NPV is zero or negative think or reject.

Option value concept takes into account NPV but also the strategic value of investments. When companies take on investments for which the value of NPV is negative they often refer to "strategic value" of the investment. Real options that are common in capital investment projects may be divided into four groups (Brealey and Myers, 2000):

- The option to make one or several follow-on investments, if the immediate investment project succeeds,
- The option to abandon an investment project,
- The option to wait and learn more before investing,
- The option to vary the company's output or its production method.

Options are, generally spoken, about reserving the opportunity to receive something at a later stage in time. Option value can be useful, for instance, in a situation where adopting an environmental protection measure would not be economically sensible today, but neglecting to adopt it would cause the entire production to stop after 10 years.

Possible uses: Option value encourages the management to consider carefully strategic consequences as opposed to only looking at expected financial returns over a period of time.

Annualised Capital Charges is a tool promoted by, e.g., CONCAWE AQ[2] for determination of annualised costs of environmental investments. Capital charge is defined as the before tax annual operating income that would make a particular project just meet the desired return. Achieving this operating income and setting the discount rate at the desired level would give the investment project the net present value (NPV) equal to zero. Capital charge is usually calculated as a percentage of capital expenditure.

Environmental investments are capital expenditures that usually are not expected to create revenues/incomes. Therefore the NPV would have to be applied to environmental investment appraisal in a modified way. A suggestion is to assign dummy constant yearly revenue for the environmental investment and

2. CONCAWE is the oil companies' European organisation for environment, health and safety.

through that derive the annual cost for an environmental investment. The annual income could then be calculated per ton of emissions. A prerequisite for this kind of evaluation is that the allocation of the investment is done correctly.

> **Possible uses:** A tool for calculating the price of a unit of pollution abated. A modification of this method is to interpret the constant revenue as the limit of "avoided costs"[3].

Cost-effectiveness Analysis is a framework that combines monetary values with non-monetary values (for instance, money vs. quality of life, emissions). It has been commonly used for evaluating the benefits of, e.g., health projects. Cost-effectiveness analysis is also useful in combining the economic costs and environmental benefits of a given investment. The method receives credit from disclaiming translation of environmental measures into arbitrary monetary values. The key question to be answered is what is the most cost-efficient way to achieve minimum emissions using the measures available.

> **Possible uses:** A framework for taking non-monetary benefits and "revenues" into account when planning a new investment or evaluating an already implemented one.

4.2.2 Cost allocation

Costs involved with environmental protection measures should be allocated correctly. It has been demonstrated by empirical studies that the company could actually realize many times higher savings if investment decisions for environmental protection measures were based on correct allocation rules (Schaltegger et al. 1996). Earlier, it was thought that information costs exceed the benefits from being informed. Now the situation is quite the opposite, partly due to stricter environmental regulation and partly due to the decreased information delivery costs.

Activity-Based Costing (ABC) is sometimes also called Activity Based Accounting. The method originated from a project by CAM-I[4] in the late 1980's. ABC method is based on allocation of the internal costs to cost centres (i.e., production processes) and cost carriers (i.e. products). The allocation follows the basic principle that activities cause costs. ABC is actually more than just an accounting system – it also serves as a strategic management tool – used by companies and organisations.

Adopting Activity-Based Costing requires a new way of thinking. A prerequisite for applying it is that the company promotes activity-based management and practises activity based accounting. A practical example applied to water treatment: instead of budgeting for the equipment, the company allocates money to the treatment of water as such. Next we can identify the cost centres: it costs something to "take the water in", to "purify" and to "discharge the water". These are activities that cause costs that have to be allocated to cost carriers, i.e., machinery, labour etc.

A three-step allocation process of costs can be used:

- Joint environmental cost centres (e.g. water treatment plant) to production cost centres,
- Production cost centres to cost carriers,
- Other environmentally induced costs to production cost carriers.

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3. These costs are expenses that the company would have incurred had it not made the investment.
4. Consortium for Advanced Manufacturers International

The chief indicators for environmental impact used in the allocation process are called "allocation keys". The allocation keys can be divided for instance into the following four categories:

- Volume-based indicators,
- Harmfulness/Toxicity-based indicators,
- Added environmental impact of the emissions treated,
- Induced relative costs involved with treatment of different kinds of emissions.

Possible uses: ABC is a useful tool for dividing overhead costs between the production units or processes. When the costs have been correctly allocated to the cost centres (parts of the production process) the method helps to reveal where value is added or destroyed. The company in this way identifies where they can most effectively improve their production process. For efficiency evaluation purposes, ABC should be complemented with a method that also includes capital costs.

4.3 Demand effects and cost appraisal

Obviously demanding extra investments from a company to comply with environmental regulation incurs costs that somehow have to be attributed to departments in a company and eventually should end up in the unit cost of a product (or the products) to which the investment relates. Various ways to realise cost attribution are indicated in Chapter 4. In the explanation given so far it is assumed that not any kind of response at the demand side occurs. In some circumstances demand responses have negligible additional effects compared to original change in cost due to the investment. To neglect the impact beforehand can however lead to serious miscalculation of both unit cost and total cost effects.

In order to categorise the various situations that may occur we follow a step wise questioning sequence:

1. Is the (extra) investment due to compliance to environmental standards sufficiently distinguishable from other components of the investment? If the answer is no, another kind of analysis is needed (see below), otherwise continue this list.
2. Does the investment cause a significant change in unit cost when production levels would remain the same? (A significant change in unit cost means a change that is large enough to force the producer to adapt sales prices of the goods involved.)
3. If the answer to Q2 is 'no', there is no defensive need for adapting prices and hence the rest of the demand impact analysis can be skipped. There may be offensive reasons to adapt the price, for example as long as a part of the competitors has not yet done the same investment, while at least a part of the customers seems willing to pay a premium for an environmentally sound product even if it didn't cost the producer anything extra to produce it.
4. If the cost impact is significant (the answer to Q2 is 'yes'), while the extra investments for environmental purposes are distinguishable, we assume here that it means a significant rise in unit cost. A significant rise in unit cost implies an increase in sales prices. The increase in sales price causes a response of the customers. The key question is, to what extent are the customers price-sensitive, or in jargon: is the price elasticity high or low?
5. If the answer to Q4 is 'low'. It seems possible to pass on most or all cost to the buyers by raising the price, since the amount of lost sales will be small in this case. For example, a 5 % price rise that leads to only a 1 % reduction in sales. In that case there is no need to resize the whole investment as probably no production capacity needs to be skipped, unless production volumes are large and spread out over many units.

If the answer to Q4 is however 'high' the impact on demand volume should be assessed. Next the company decides either to translate the cost rise entirely into a price rise or to swallow a part of the cost by accepting smaller margins. Subsequently, when the price rise is known the resulting impact on demand and production volume can be calculated. If the changes are large enough to justify shedding of production capacity, the environmental investment probably needs resizing as well. Finally the total cost and unit cost effects of the adapted environmental investment should be assessed.

Sometimes the investments for environmental purposes are not distinguishable, for example because a whole set of equipment is changed, often implying all kinds of technology changes and changes in shares of labour cost, material and energy cost and capital cost. The cost attributable to compliance with environmental regulation, can be estimated by comparing alternative investment packages, e.g., taking one package in which just new vintages of the substituted machinery are chosen and the alternatives in which really new technology is used. The cost difference between the packages can be wholly or partly attributed to environmental compliance, depending on information on other reasons for extra cost. Once the attribution is settled the above steps 1–5 can be followed.

If also package comparison is impossible, it is wiser to assume zero extra investment cost, unless earlier experience and literature can give clues on applicable figures. Otherwise only extra operational cost – if relevant – may be attributable to environmental compliance.

So far we have been assuming that companies are acting because of new regulation. This could be regarded as defensive or reactive behaviour. Companies can also be pro-active in environmental affairs. This can happen, if the company somehow expects to earn a premium in the market based on the claim to be one of the first producing according such and such standards. It would mean that customers are prepared to pay the extra cost allowing the company either to increase its margins and/or to increase its market share. Therefore in those circumstances the environmental investment is part of an offensive strategy.

4.4 Summary

Environmental costing is increasingly important for companies. At the same time, when environmental measures have shifted emphasis from end-of-pipe-type technologies to process-integrated measures, the task of allocating the costs has become increasingly difficult. Allocation of costs or distinguishing and separating the costs of an environmental investment from other investment is also certainly among the greatest challenges to environmental costing. (On the other hand, there is the viewpoint that an integrated assessment should not separate environmental investments from other investments.) Activity-Based Costing is based on the attempt to assign costs according to activities. This would enable a company to locate value added or destroyed in the production process.

Option value incorporated into traditional investment appraisals is a useful notion that takes into account not only the discounted value of an investment, but also possible strategic implications.

It should be emphasized that even applied to traditional economic investments none of the single methods is perfect. In addition to costs, also demand factors have to be considered. Environmental investment analysis adds pressure to create a wise combination of the methods to apply. Table 1 summarises costing tools and their applicability to environmental investment analysis.

Each of the methodologies is at this stage described, as it would be the application for a single company or production site. When evaluating the method's suitability as a standard tool for BAT investment evaluations, a broader approach should be taken.

Table 1. Summary table on costing tools and their applicability to environmental investment.

Costing tool	Status	Pros	Cons	Comments
Total Cost Assessment (TCA)	Appraisal framework	–	–	General investment appraisal framework
Net Present Value (NPV)	Calculation method	Takes into account the flow of future incomes	Selection of discount rate has a significant impact on results.	–
Option value	Concept	Strategic implications of an investment may be included	Quite abstract.	Useful concept to consider – especially in case of environmental investments.
Cost-Effectiveness Analysis	Evalution Method	Helps to identify effectiveness of an an unvestment in terms of e.g. cost/ reduced pollution.	–	Common sense. Does not require assigning arbitrary costs on nonmonetary assets such as pollution.
Activity Based Costing (ABC)	Accounting Framework	Tool for allocating the impacts of environmental investments on the parts of the production process.	Method does not account for capital charges.	–

5 Evaluation of environmental harms and benefits

5.1 Introduction

In the IPPC context, the environmental harms and benefits of an industrial installation are caused by the emissions into water and air, waste streams, use of energy and raw materials. A common way of assessing the harms and benefits is to distinguish the impacts on ecosystems, human health, amenities and other uses. On the other hand the impacts can be classified on the basis of their geographical scale into local, regional and global categories.

The scope of the IPPC Directive is limited to the environmental aspects of an industrial installation including the use of raw materials and energy efficiency. Hence the scope does not extend from cradle-to-grave of a product system but rather from the main upstream processes to gate or gate-to-gate of an industrial plant (Figure 11), which clearly has implications on the evaluation of environmental harms and benefits.

The following issues are usually determined step-wise in the evaluation of environmental impacts caused by an industrial installation:

1. Quality and quantity of emissions of harmful substances, waste, noise and thermal load including the temporal variations and disturbances;
2. Transportation, degradation, accumulation and transformation of emitted harmful substances and the exposure of organisms, humans and structures;
3. Impacts of emissions, waste streams, noise and thermal load on organisms, populations and habitats as well as on human health and amenities; and
4. Significance of impacts from the point of view of natural ecosystems, humans and society;
5. Efficiency of energy use and environmental aspects of raw materials.

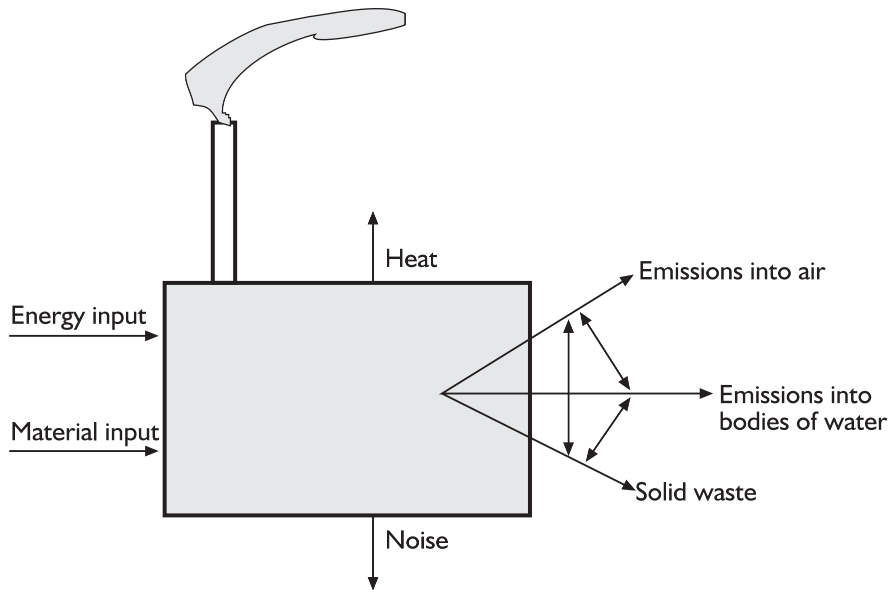


Figure 11. The inputs and outputs of an industrial installation considered in the IPPC directive.

In practice, the evaluation must focus on the most significant and relevant emissions and other impact factors. The main steps of the assessment of environmental harms and benefits in the integrated environmental permitting according to the Finnish Environmental Protection Act (entered into force 1st March 2000) are shown in Figure 5-2.

From the point of view of permit deliberations, it is essential that the effects of different category indicators be assessed in different ways. As for global or transboundary problems, i.e. climate change, ozone depletion, photochemical oxidant formation, acidification and airborne nutrification no quantifiable impact can be specified for an individual installation even though each installation has a quantifiable emission which contributes to the problem. Concerning the acidifying and toxic airborne emissions of an installation, quantifiable impacts can sometimes be perceived in the vicinity of the plant while the bulk of the emissions are dispersed as transboundary pollutants.

The contributions of an industrial plant to environmental aspects such as eutrophication, oxygen depletion and suspended solids in receiving waters, particles in the ambient air, waste generation, biodiversity, noise and odours are characteristically local and to some degree quantifiable.

The amount of information required by an impact assessment strongly depends on how comprehensive, sophisticated and accurate the chosen assessment method is. Hence different types of methods and approaches have been adopted for different types of emissions. Greenhouse gas emissions and emissions of ozone depleting substances, photochemical oxidants, airborne nutrifying substances and acidifying substances are transported in the atmosphere over long distances and no direct local impacts can normally be observed. Global and continental conventions with national scale restrictions are drawn up to curb these harmful impacts. In the case of greenhouse gas emissions it is up to the national level to decide on how to control these emissions in order to meet the international obligations. In Finland a national strategy for climate change has been drawn up. The necessary measures will be determined by the Council of State. For ozone depleting substances the product bans and restrictions have proved to be effective policy instruments. In the case of photo-oxidants, acidifying substances and nutrifying substances there are at the same time usually the national ceilings and emission norms or limit values directly setting minimum requirements for installations.

In case the emissions do have some noticeable impacts on the surrounding natural ecosystems, the degree of acceptable change must be determined. For toxic impacts the acceptable change is usually set at a very low level whereas for impact categories such as eutrophication and oxygen depletion in water bodies, increase in turbidity and temperature the acceptable change might be set at a higher level. The acceptable change may be determined case-by-case or by national legislation. Sometimes toxic impacts can be totally prevented by means of chemical product bans and restrictions. According to the so-called combined approach, both emission limit values are set for emissions and environmental quality standards are issued to secure the minimum environmental status. This approach is applicable to the reduction of those emissions whose impacts can be measured.

Impacts affecting directly human health and living conditions, such as particles in air, carcinogenic substances, odorous substances and noise are usually evaluated against legal norms securing healthy and comfortable conditions in the surrounding environment.

5.2 Evaluation of environmental impacts

The notion of integrated pollution prevention and control of an industrial installation calls for the identification of emissions and other environmental aspects, which might have an impact on the environment, human health and human activities as a whole. The intake or release of substances and energy can be quantified by means of measurements, calculations or expert judgements.

Emissions impact evaluation is based on the inventory (quality and quantity) of the released substances. Since a number of substances contribute to certain types of impacts, the released substances can be grouped under certain impact categories. This type of approach has been adopted for example in life cycle impact assessment explained in Appendix 1. The grouping is also to some extent applicable to integrated environmental permitting.

Modelling of fate (dispersion and distribution) and exposure of emitted substances is usually required for reliable assessment of local nature and human health effects. Evaluation of their significance in the local environment further requires that the quantified effects, e.g. increased concentrations in the media or organisms, be assessed against appropriate environmental objectives or standards. In integrated environmental permitting, the primary points of reference are the environmental quality standards and objectives set in national and Community (European Communities) legislation.

To a large extent, the environmental impact assessment (EIA) procedure described in the EIA Directive (85/337/EEC, am. 97/11/EC) follows the same basic steps as the environmental assessment done under the IPPC Directive in environmental permitting. Nevertheless the social, cultural and economic impacts tend to be more pronounced in the EIA procedure as compared to the IPPC context. The social evaluation might include the impacts on direct and indirect economic aspects and employment. On the other hand in the environmental permitting, securing the legal rights of persons and the healthy living conditions are strongly addressed.

The framework for integrated evaluation of environmental harms and benefits in the Finnish environmental permitting is depicted in Figure 12. Important specific features in permitting that have to be taken into consideration in conjunction with the evaluation of environmental harms and benefits are:

- Assessment of technical processes and purification measures
- Emission norms and bans
- Environmental quality standards and noise standards
- Product restrictions and bans
- Legal provisions on waste
- Use of the impacted area, e.g. residential areas, water supply, recreation
- Specific nature or other values of the impacted area, e.g. nature protection, groundwater protection

In environmental permitting there is a multitude of norms and targets, frequently changing in time, concerning emissions and state of the environment, often based on the Community Law or other international agreements. According to Silvo *et al.* (2000), the environmental assessment based on analytical and versatile approaches taking into consideration the common set of norms and targets suits well for the permitting process. Well-developed and commonly accepted sets of environmental quality objectives support substantially the permitting process. Aggregation of different types of impacts in environmental permitting can be seen as an additional, supportive methodology.

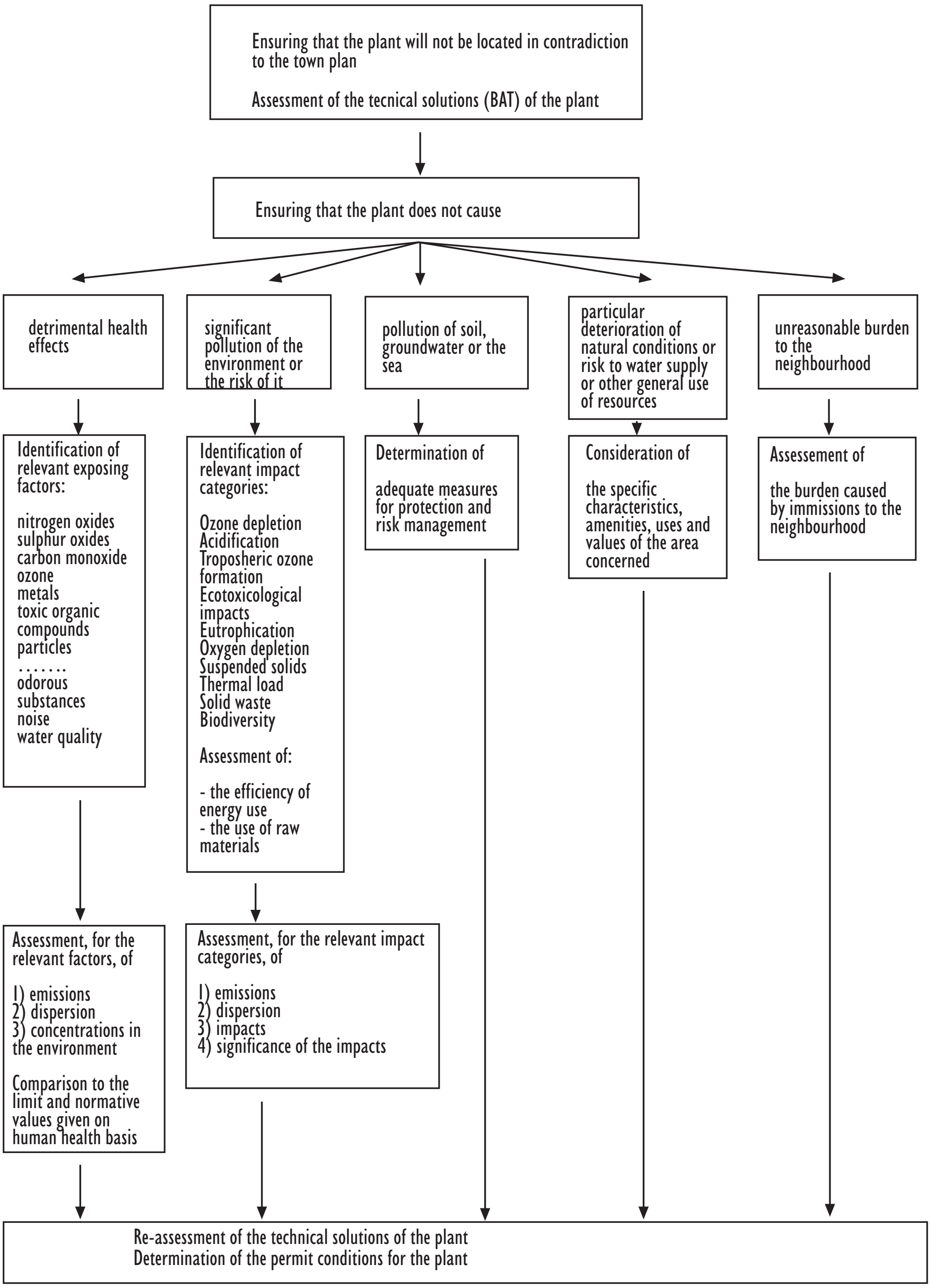


Figure 12. Phases of the environmental impact assessment in the permitting process according to the Finnish environmental protection act (Silvo et al. 2000, Melanen et al. 2001).

5.3 Aggregation of impacts

Aggregation of different types of environmental impacts has been developed particularly in the context of life cycle assessments and environmental cost assessments (monetary valuation of environmental harms and benefits).

In life cycle assessments, a typical approach to calculate the value of an aggregated impact indicator V (a) of a product system (a) is the following:

$$V(a) = \sum_{i=1}^{n} w_i \frac{I_i(a)}{N_i}$$

W_i = weight of impact category i,
N_i = normalization factor of impact category i,
$I_i(a)$ = environmental impact of impact category i in a product system (a)

In formula (1), the normalisation factor N_i is the total value of impact category indicator of a certain area (e.g., a country) over a certain period of time, e.g., one year. Thus, normalisation produces a relative proportion of impacts caused by a product system against a certain reference value. The normalised value of an impact category indicator gives a rough idea of the significance of different emissions contributing to certain impact categories.

The weighing of different impact categories against each other is usually based on the following approaches:

1) Distance-to-target methods;
2) Expert or group preferences; and
3) Monetary valuation;

In **distance-to-target method**s, the weights of the impact categories are determined by the differences in the distances between the present situation and the generally accepted target for a particular impact category. The target level may have been defined, e.g., as ecologically sustainable level or politically acceptable level. The distance-to-target approach has been applied in several LCA methods (e.g., ET-method, Baumann and Rydberg 1994; Eco-indicator 95, Goedkoop 1995). One has to be cautious of the applicability of the method to a particular type of impact.

Methods related to the use of **expert panels** produce results based on the respondents' preferences over the differences in the significance of different impact categories. The task may consist of the following phases: selection of respondents, preparation of background information, selection of the questioning technique, questioning, calculation and interpretation of the results. There are alternative ways to carry out the different phases, the effect of which on the final results is quite poorly known.

The determination of weights based on the preferences of experts, interest groups or other groups can be done using several techniques. In decision analysis approach such techniques include, e.g., trade-off method, swing weighting method and ratio method.

In the Finnish sector level LCAs on forest industry (Seppälä and Jouttijärvi 1997), food production (Grönroos and Seppälä 2000), metal production (Seppälä et al. 2000) and South-Savo Province economic activities (Tenhunen & Seppälä 2000), the impact category weights were determined by expert panels using the ratio method. First the impact categories were asked to be ranked in the order of their significance. Then the respondents were asked to determine the relative differences between the impact categories. The questions were formulated in the following exemplary manner: "In your opinion, how much more important is it to reduce acidifying emissions rather than eutrophying emissions in Finland (or vice versa)?" The average values of the weights in the four studies are shown in Figure 13. It can be noted that there are significant variations in the results of different expert panels in different times even within one country. In these studies, the variations were greatest for climate change, acidification, eutrophication and loss of biodiversity. The weights of climate change and eutrophication seemed to have increased during the 3-year period, whereas the weight of acidification decreased. One could conclude that the degree of subjectivity in weighting based on expert panels is considerable, although the process itself may be very useful by inducing a structured discussion.

Monetary valuation of environmental impacts is founded on the idea that an economic value can be determined for a certain environmental harm or benefit. The differences in the values reflect directly the weights of different impact categories.

The suitability of various monetary valuation methods for the total environmental costs in connection with a plant level evaluation was assessed by Silvo et. al. (2000) and further demonstrated by Melanen *et al.* (2001). The methods examined included Impact Pathway Method (IPM), Aversive Behaviour Method (ABM), Hedonic Pricing Method (HPM), Contingent Valuation Method (CVM) and Benefit Transfer Method (BTM). The methods were compared with respect to their validity and reliability, comprehensiveness, completeness and practical applicability. In addition, the methodology used has to be consistent and transparent. In the case analysis of an integrated pulp and paper plant the methods shown in Table 2 were applied. The socio-economic benefits such as income effects and employment created by the industrial activity were not dealt with in the case study.

It was shown in the study that monetary valuation of environmental impacts on plant level might be used as supportive information in the permitting process. The environmental costs arising from atmospheric emissions may be evaluated by means of the impact pathway method employing exposure-response functions. The costs of applying the method and the time required for the assessment may, however, in most cases be considerable.

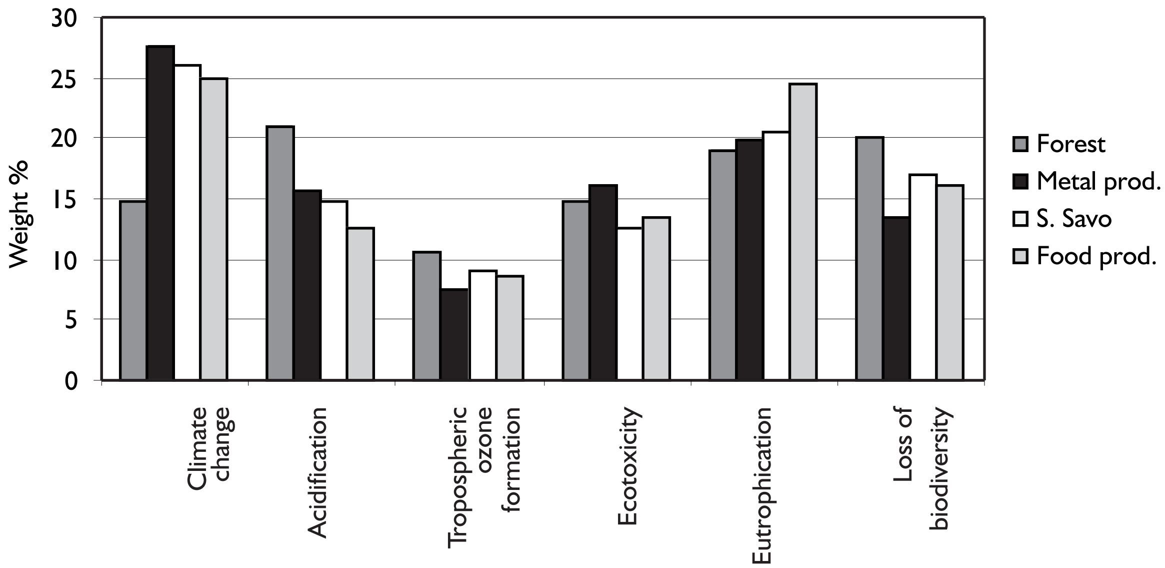


Figure 13. The average impact category weights in various Finnish LCA studies.
(n= number of experts): forest industry (Seppälä and Jouttijärvi 1997) n=59, metal production (Seppälä et al. 2000) n=37, South Savo province economic activities (Tenhunen and Seppälä 2000) n=17, food production (Grönroos and Seppälä 2000) n=17

Table 2. Methods used for the monetary valuation of environmental impacts (Silvo et al. 2000).

Stressors	Impact	Methods
Emission into air	Impacts on health, material damage, forest damage, crop damage, effects on water bodies (see below)	Impact Pathway or Benefit Transfer based on Impact Pathway or Contingent Valuation
Emissions into waters	Recreational values	Benefit Transfer based on CVM
	Fisheries	Changes in fish populations combined with market values
	Water quality	Aversive behaviour
Noise	Amenities	Benefit Transfer based on Hedonic Pricing
Odours	Health	Impact Pathway
	Amenities	Benefit Transfer based on CVM
Waste	Impacts on nature	Waste treatment costs
	Amenities	Benefit Transfer based on CVM or HPM
Emissions into soil (contaminated soil)	Most impacts	Restoration costs

For external environmental costing the bottleneck for application is quite often the lack of relevant quantitative data on impacts and unit costs. It must also be recognised that there are no credible exposure-response functions available for all impact pathways, e.g., health effects of nitrogen oxides, cultural values, economic and recreational value of forests and biodiversity. High quality data for unit costs are also lacking for some harmful environmental and health effects.

The benefit transfer method might be applied instead of the impact pathway method, if adequate basic data and time are not available, but inevitably this would increase uncertainties in the results. In Finland, the background data for the monetary valuation of air and water emissions is fairly satisfactory for practical applications, whereas the monetary valuation of noise, odours and waste requires more investigations to cater for routine applications. In the interpretation of the results, the issues that the monetary valuation methodology does not address adequately must be taken into account. These include, e.g., the existence and subsistence values of nature, rights of the future generations and the effect of casual events.

As a whole it can be concluded that a great deal of uncertainty and subjectivity is related to all weighting methods. Hence one has to be extremely cautious of the many-faceted implications, if weighting is applied to the evaluation of the environmental harms and benefits.

Integration of economic and environmental aspects

6

6.1 Introduction

The problem tackled in this report could be seen as trying to reconcile private sector and public sector objectives by trying to link up the different assessment methods. Eventually we want to have a process that ensures that environmental targets are met, with minimal harm to the economy, while this coincides as much as possible with a company level assessment in which at minimum cost (or maximum benefits) at least the environmental standards or a weighed multi-effect benchmark of that are satisfied in order to get a permit.

Environmental assessments are mostly multi-dimensional, since often already in the physical realm various effects have to be considered (e.g. acidifying emissions and noise). Furthermore, the assessment is often related to the attainment of particular minimum standards formulated in a public or company policy. As a consequence environmental evaluations may use multi-criteria analysis (MCA) including weighing procedures for various effects and their seriousness.

Economic assessment methods are – eventually – one-dimensional, meaning that eventually monetary costs are attributed to impacts and to efforts to mitigate the impacts. In the context of this report the focus has been on private sector cost-benefit analysis (CBA) and investment appraisal. One should realise that any effect that is negative or positive to society, but which does not affect any performance in the company itself, is not taken into account in a private sector CBA or investment appraisal. This would only happen, if that so-called 'external effect' would become a policy issue, e.g. by putting levies on its source or specifying limits for emissions or degree of impacts. In that case the policy has made the environmental problem internal to the decision-making context of the companies.

In public policy MCA's the so-called internalisation of external effects can be an important element, including effects that have not (yet) been taken up by policy measures. Furthermore, the shadow price (weight) attributed to an effect can differ from the current price at which it is internalised. Last but not least, single project based assessments, also when they internalise the relevant environmental effects, may still result in a priority rating of alternatives, which is not optimal from a macro-economic point of view[5]. As a consequence policy makers and policy implementers on the one hand and private project evaluators on the other hand usually have to reconcile their initially dissimilar preference lists and targets. Basically there are two ways to reconcile:

- To agree on minimum environmental standards plus perhaps a combined benchmark and for the rest the economic assessment will guide the decision-making (provided there are regular checks to see whether the environmental standards are not violated).

5. For example, if a society suffers from substantial unemployment, the marginal costs of an employee are higher to the company that considers to hire (or fire) an employee than to society. A discussion of the evaluation requirements and implications of the comparison of private economic and public (social) economic assessments go beyond the assignment of this study. It is recommendable to pay attention to these issues during policy formulation and reviews.

- To specify first a set of economic performance standards for broadly identified strategies to tackle the problem (e.g. project ROI and influence on company's ROI). Subsequently, one tries to achieve the best possible environmental quality (and perhaps other policy goals), while checking regularly on minimum economic performance.

The process is summarised in Figure 14 below. The separate processes need to move towards each other in order to obtain matching norms and goals. These processes will always be stepwise, including a lot of feedback. The starting point and extensiveness of the assessments and decision-making process depend on the actual circumstances.

It is hard to say a priori which way to choose. It depends on the context. However, generally speaking one could say that the first mentioned approach (CBA as prime guidance, environmental performance requirements as checks) fits better at the detailed level of policy implementation notably at single project/plant level. The CBA tends to be case specific anyhow. Indeed in case the evaluation concerns policy preparation or if it deals with a whole sector or at least a whole (multi location) company the second approach could be wiser, at least in initial stages of assessment.

6.2 Conclusion from Chapters 4 and 5

The parallel chapters 4 and 5 presented partially overlapping methods for costing and assessment of environmental impacts. Combining these chapters, we can present conclusions in the shape of a series of questions and answers:

- Is there a need to use these types of methodologies? **Yes** – without them, any relevant evaluation will be sorely lacking in substance.
- Is there one method, which should be chosen as the standard? **Definitely not**. The methods highlight different aspects of the issues and, used alone and without carefully considering their weaknesses, run the risk of a seriously skewed picture.
- If we can only use one method, which do we choose? That depends entirely on the situation. The question asked, the goal of the study, the circumstances all dictate the choice – which may not be easy.
- Even when using a carefully selected method (or combination of methods), what is essential? Being aware of, discussing and considering the particular weaknesses of the methods chosen and the consequences.

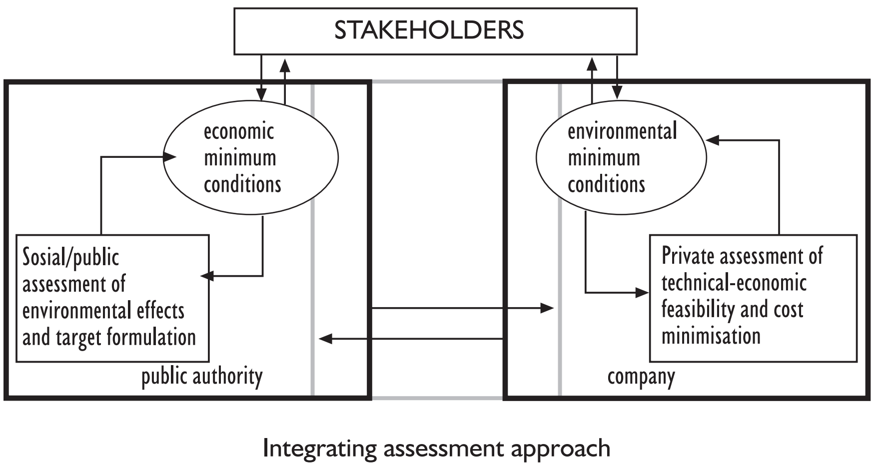


Figure 14. Reconciling private and public sector objectives.

6.3 Key concept: value

Value can be added or destroyed. At a certain point there is a cross over at which time for example the value of a product becomes negative, as it is classified as waste. This could be called "value crossover" of cross-media impacts (Figure 15).

Value is a slippery concept, since it contains both objective and subjective elements. In economics the objective value of a good constitutes the components from which it is made, being the input of capital, labour, material, energy and – nowadays – knowledge. The subjective value is the value that a good apparently has on a market (that what the clients want to pay for it). If the subjective value is smaller than the objective value, there is not much point in making the good. If, despite the negative balance between subjective and objective value, a good is nevertheless produced, a subsidy is needed that should be justifiable on the basis of special merits (the 'merit good principle' referring to positive social, environmental, etc. effects).

If we look to a production process as a whole we can see that by combining inputs value can be added and therefore the final product can be sold with a profit while still all parties get their share of the objective value. However, although the whole process creates a lot of value, there are also the remains of the process that cannot be sold anymore and therefore become waste, i.e. there is not any subjective value left. In most cases the value is even negative, since the waste causes environmental damage that needs to be repaired or compensated and/or the waste treatment incurs at least cost. The challenge is to delay the cross-over point to waste (Figure 15) and to take care that elimination of negative value is not translated in an equal reduction of the value added in the primary process, but in a much smaller one or even none. Next to technical investments that reduce the waste volume or turn it into valuable goods, the creation of markets can help. Sometimes the subjective value is (assumed to be) zero, because the waste generating company does not know where to find potential customers. For example, internet-based systems can be a cheap way to create or enlarge markets for recycled products.

The value analysis is based on the value cross-over diagrams, where a process chart is combined with the value dimension.

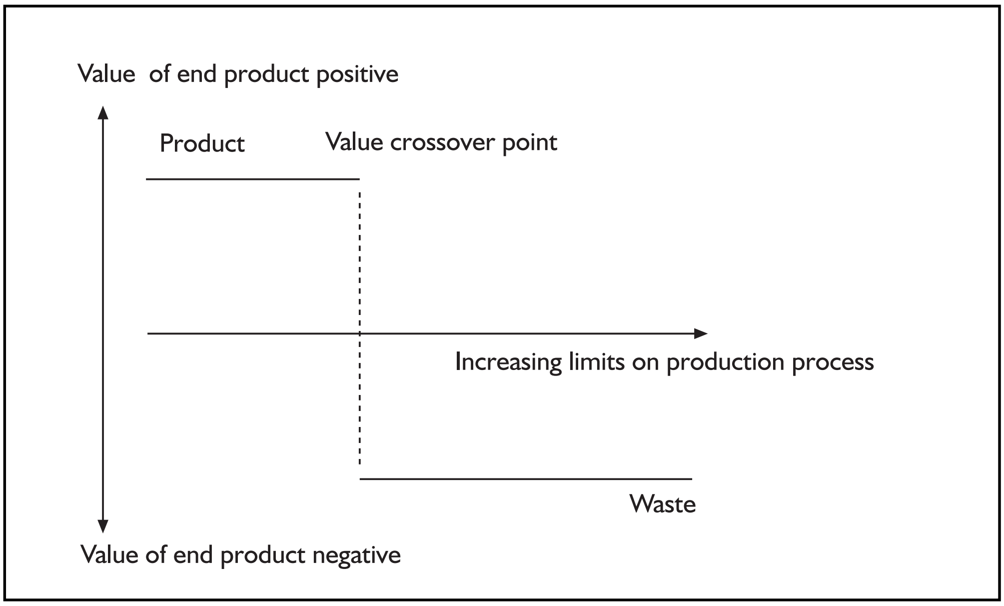


Figure 15. Value crossover.

6.4 The combinatorial principle: the switchboard

In combining the evaluations, we do as follows:

- We look at different economic methods
- We look at different environmental methods
- Then we combine these as if in a switchboard for the cases (Figure 16)

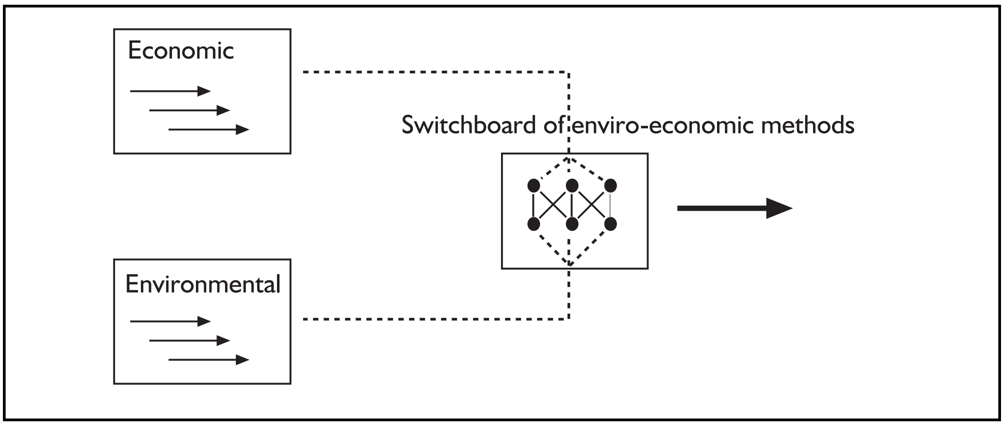


Figure 16. Switchboard of methods.

6.5 Plot for method combinations

6.5.1 Starting point

In a framework for cross-media assessment, a scientific basis must be linked to practical solutions. Encountering and solving cases in practice promotes deeper understanding of cross-media phenomena.

To establish such a framework, we need

- A guiding principle and
- Practical tools and guidelines

Our guiding principle is what we call "The Lens Principle", our tools include the "Cross-media Action Table" and the "Perspective List".

6.5.2 The lens principle

The basic idea: The more complex and serious the cross-media problem, the wider the angle of different perspectives needed, that is: More serious cross-media clashes require more analyses.

In a simple case, a smaller selection of analyses is sufficient; in a complex incident, many viewpoints are needed. It also depends on what "lens" we are using when looking at the problem.

The lens aperture can be visualised, e.g., by using the work "Day and Night (1938)" of the Dutch artist M.C. Escher and calling it "Pure and Polluted" (Figure 17).

In "Day and Night", a Dutch landscape is not quite what it seems – or perhaps it is.

However, the work also contains the media: water (the river flowing through), air (the birds) and land (the Dutch soil). We can also imagine a transformation from right to left or vice versa: from the light, pure landscape on the left to the dark, polluted landscape on the right. In the version on top, we have a small

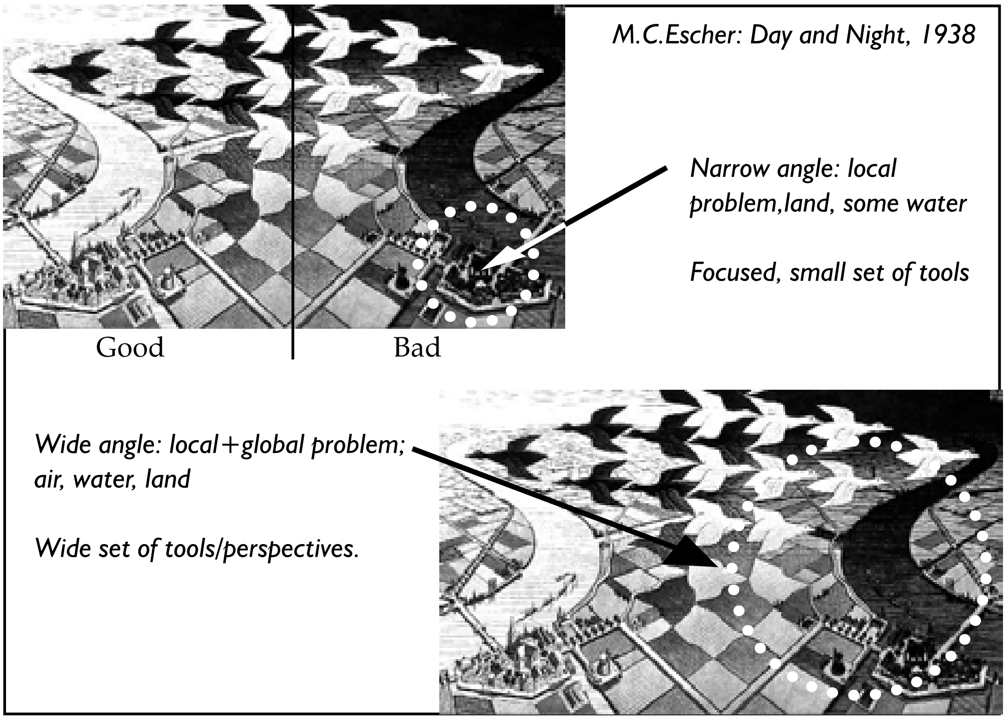


Figure 17. The lens: pure and polluted.

lens: we are looking at just a local problem involving land and water, needing a small set of tools. In the version on the bottom, a wider view brings in all the media and necessitates a wider selection of analyses.

6.5.3 The cross-media action table

The table

The "Cross-media Action Table" is depicted in Figure 18.

In the table the types of problems are identified with a combination of the following codes:
0 = no environmental impact,
i = improving situation, positive environmental impact,
w = worsening situation, negative environmental impact.

The "Cross-media Action Table"[6] flows from left to right, containing answers to the questions:

- **What is the cross-media situation?**
  A flowchart of cross-media classification and an encoding of cross-media effects
- **What is our aim?**
  Environmental objectives (established for a specific case)
- **What actions should we take?**
  Measures and sub-measures to be taken (related to environmental objectives). Actions include analyses to undertake from the Perspective List.
- **What are the measurable environmental and economic goals?**
  A baseline and a target (on a timeline), with measurable environmental and economic objectives

6. The Action Table has structural analogies with work in strategy mapping in Kaplan and Norton 2001.

- **What investments are needed?**
  Related environmental and other investments
- **What is the cross-media situation? Classifying the cases**
  A possible system for classifying the cases is shown in Figure 18. In the system, we can have
  - A stable state: nothing changes as a result of activity
  - No cross-media clash: the changes go in only one direction
  - Minor and severe cross-media clashes: contrasting effects

  If we want to expand the table by introducing new impact types, the recommended method is to
  - Add two dimensions: energy and "special circumstances" (an umbrella for various other impacts, e.g. moving the problem in time and space for somebody else to deal with)
  - Use the receiving media cases in Figure 18 as basis, and add coding for the two new dimensions
- **What is our aim? Establishing environmental objectives**
  The environmental objective is either given from the start or modified when the situation is examined.
- **What actions should we take? Measures and sub-measures**
  Measures are something highly tangible, e.g. cutting specific emissions. Measures include performing a series of analyses (using the "Lens").

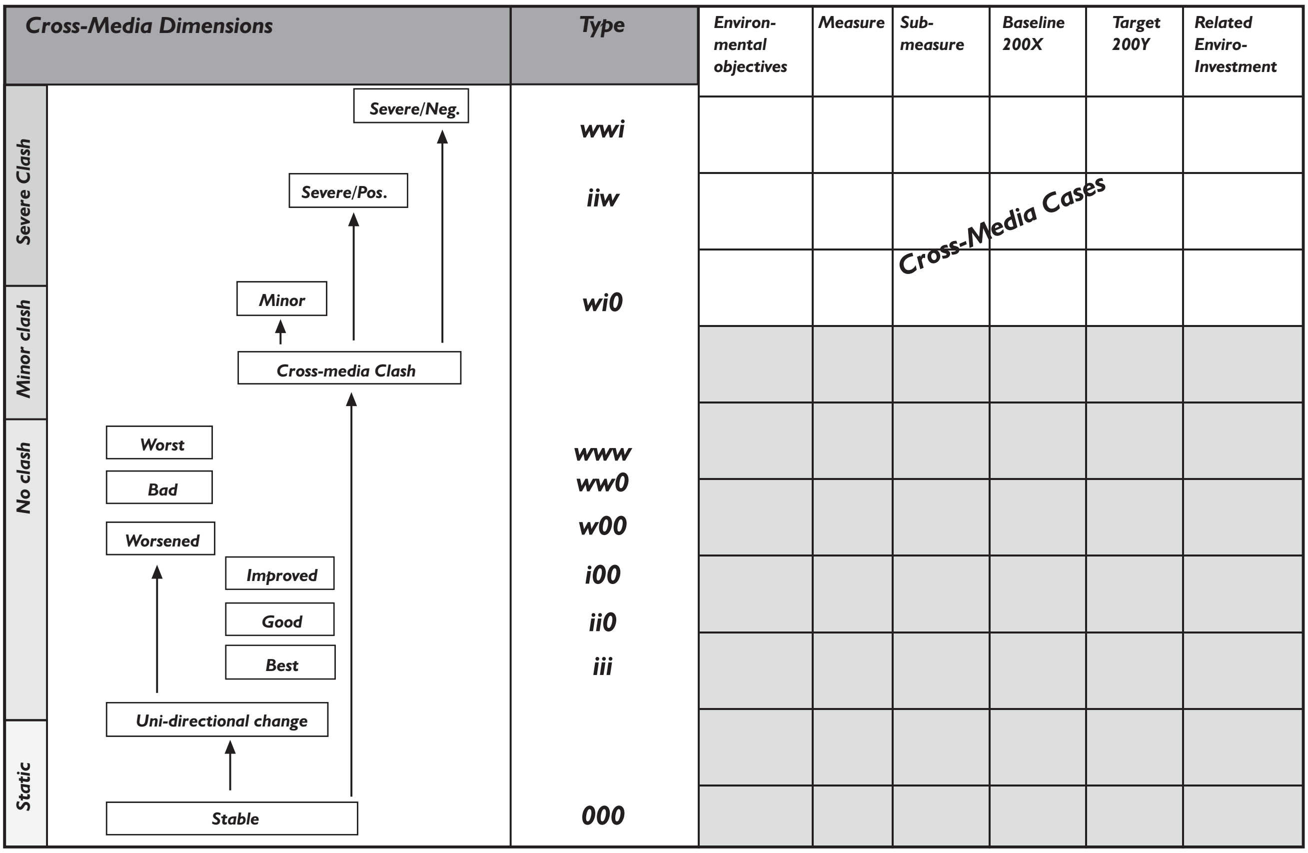


Figure 18. Cross-media action table.

- **What are the measurable environmental and economic goals? Baseline and targets**
  The baseline is the current situation for the measurable objectives (environmental and economic) derived from the previous parts of the table; the targets are the measurable goal.
- **What investments are needed? Related environmental investmen**t
  Any related actions are enumerated here.

Examples
Figure 19 below is (an outline of) an example of the action part of the table for three specific cases of different types.

6.5.4 The perspective list

The "Perspective List" is linked to the classification part of the Action Table. The list is a set of recommended combinations of analyses to perform for certain basic types of cases. Insofar as it is possible, the different perspectives are given names.

The list is an aid. The analyses to perform depend on the specific cases. Common sense should be used and several combinations of analyses might be reasonable.

Cross-Media Clashes	Type	Environmental objectives	Measure	Sub-Measure	Baseline 200X	Target 20YZ	Related Enviroinvestment
Severe Clash/Positive eutrophication (i) process water quality stressors (i) solid waste (w)	iiw	general: decrease eutrophication while maintaining / decreasing the level of solid waste	cut N & P emissions, minimise use of raw meaterials	continuous improvement of the production process	N xx $\mu g/l$ P xx $\mu g/l$ Solid waste zz kg/ton of product	N xx $\mu g/l$ P xx $\mu g/l$ Solid waste zz kg/ton of product	
Minor clash acidification (i) solid waste (w) water use (0)	wi0	general: decrease acidification while maintaining the level of solid waste and water consumption	cut acid emissions, minimise use of raw materials	continuous improvement of the production process	SO_2 xx mg/m^3 HCl xx mg/m^3 solid waste zz kg/ton of product	SO_2 xx mg/m^3 HCl xx mg/m^3 solid waste zz kg/ton of product	Scrubber to the new multifuel boiler
Severe Clash / Negative airborne nutrification (w) acidification (w) eutrophication (i)	wwi	general: decrease eutrophication while maintaining or decreasing the level of emissions to air and air pollutants	cut N & P emissions, minimise energy consumption	continuous improvement of the energy efficiency	N xx $\mu g/l$ P xx $\mu g/l$ SO_2 xx mg/m^3 TSP xx mg/m^3 NO_2 xx mg/m^3	N xx $\mu g/l$ P xx $\mu g/l$ SO_2 xx mg/m^3 TSP xx mg/m^3 NO_2 xx mg/m^3	An (energy consuming) investment for water treatment

Figure 19. Examples of actions.

7 Introduction to CASE studies

7.1 Sisyphus now

> *It may have been because he had injured Salmoneus, or because he had betrayed Zeus's secret, or because he had always lived by robbery and often murdered unsuspecting travellers […] at any rate, Sisyphus was given an exemplary punishment. The Judges of the Dead showed him a huge block of stone – identical in size with that into which Zeus had turned himself when fleeing from Asopus – and ordered him to roll it up the brow of a hill and topple it down a further slope. Ha has never yet succeeded in doing so. As soon as he has almost reached the summit, he is forced back by the weight of the shameless stone, which bounces to the bottom once more; where he wearily retrieves it and must begin all over again, though sweat bathes his limbs, and a cloud of dust rises above his head.*
>
> *(Robert Graves, The Greek Myths, 67.i)*

It is not because of injuries to individuals, betrayals of secrets or robbery and the murder of unsuspecting travellers that those who solve environmental problems in practice have a task sometimes reminiscent of that of Sisyphus, son of Aeolus. The modern Sisyphus

- Reaches the summit in solving e.g. a problem with atmospheric emissions
- Then, the problem rolls down into the area of effluent discharges
- That problem is solved, and the problem becomes of one solid waste (and often dust, as was the cloud rising above Sisyphus' head).

7.2 The problem of many dimensions

The amount of cross-media problems to analyse is fairly large, though not infinite. Figure 20 shows some of dimensions of trade-offs and possible conflicts. In this study, we first

- Choose the dimensions to be examined, and then
- Choose the example problems.

Flows: mass and energy – Mass and energy flows are the measures of the intensity of an action. (Vasara 1999)

Media: air, water, soil – The three media are the structure behind most environmental assessments.

Space – Space on earth is limited, both as to area and volume. Overcrowding is not only a problem down planet side: even the free orbits for satellites in near space are getting scarce. Sites are also included in this dimension, all locations not being equal. Thus, we can examine the volume of a mill and its discharges; the area taken up by the mill and its landfill and finally the site possessed by the mill and its deposits.

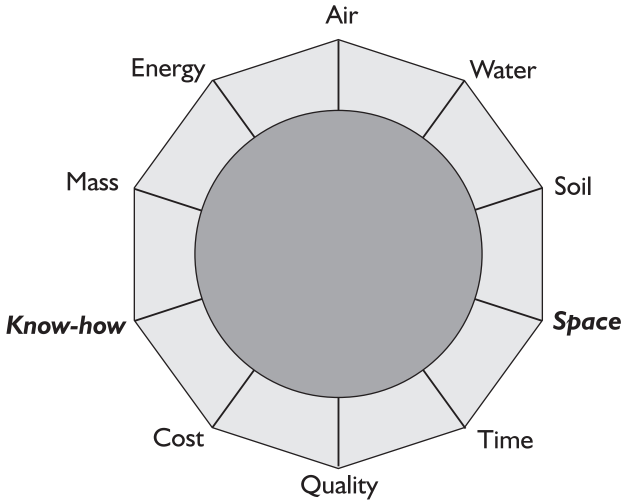


Figure 20. Dimensions of trade-offs and possible conflicts (Vasara 1999).

Time – Most of the forest sector lives to a (by human standards) slow beat: it is an industry with slow forest growth, slow external treatments, and slow investments (but with increasing mergers-and-acquisitions dynamism). Time is of the essence, and in particular the time needed to undo deviations from the path of least regrets: toxicity, loss of biodiversity and others. Everything included in the effort to undo time-consuming damage (energy, materials, discharges) can be included in the time dimension. Impacts on the duration of an activity can be expressed thus in examples where e.g. synchronisation is a problem. Time is powerful as a calculation factor; there have, for instance, been cost-benefit analyses where global warming is a boon for Finland if the time horizon is 50 years and a threat if the horizon is 200 years.

Quality – In accordance with the definition of sustainability, an activity must fulfil the requirements put on it. Quality/functionality is another aspect of this dimension. If e.g. functionality suffers while the receiving media gain directly, complicated chains of effects can bring a negative effect back to the media.

Cost – Without the resources necessary, there can be no efforts. Cost-efficiency is all the more important in environmental matters, where the problems are of a magnitude to necessitate extremely large investments.

Know-how – Often, what is needed is 1) just the right amount of 2) just the right quality/functionality in 3) just the right place. The more complex issues and processes become, the greater the need for control, knowledge, skill, innovation and know-how.

7.3 The dimensions chosen

From among the set in 7.2, we have chosen the following set of dimensions (in order of appearance in the cases):

- Cost: the dimension present in all examples – since the main dimensions are cost and environment
- The receiving media (air, water, soil): the usual dimensions, which are the logical starting point in a cumulative exercise
- Energy: an often neglected dimension, which has had to flex and bend to accommodate changes in receiving media
- Quality/service level: if the product/service offered is no longer acceptable, the whole exercise results in a total waste of all resources input

- Time: sweeping things under "the carpet of time" is a time-honoured way to solve problems in human affairs. It is also a feature of environmental issues.

This progression of dimensions is felt to be a natural one, serving both educational and other needs of the project.

7.4 The problem of many cases

As can be read also from the BAT reference documents, both the sectors of pulp and paper manufacturing and energy generation have several cases, which could be used in demonstrating trade-offs and possible conflicts in between the chosen dimensions:

The "equations" are to be read as follows: e.g. "WATER QUALITY → AIR" = by making a sacrifice/effort as regards **effluents/water consumptio**n and **end product quality**, gains in **emissions to air** are realised.

Wet scrubbing / WATER → AIR Wet scrubbing (washing gases with alkaline solution or slurry) has proven its worth in sulphur dioxide reduction. High water consumption follows, and functional difficulties in the shape of sludge disposal problems may follow.

Dust suppression / WATER QUALITY → AIR On some sites of recycling waste storage, dust suppression is of significance. Dust suppression water-sprays at the waste tipping bays can be used. The result: a small increase in water consumption and in the moisture content of the waste. The latter may cause some functional problems in incineration and landfill.

Combustion / AIR → AIR In combustion, there is a trade-off between on one hand NO_X and on the other hand CO and hydrocarbons (H_XC_Y) and other harmful gases.

Stack / SOLID WASTE → AIR Diminishing atmospheric emissions by collecting grit and dust from a stack brings with it additional solid wastes.

Closed-cycle / AIR → WATER Measures for reducing fibre line effluents by closing up the water circulation system, leads to a higher organic and also inorganic nitrogen load in the recovery process, resulting in increased fuel based NO_X emissions from recovery boiler. In optimal burning conditions the NO_X generated in recovery boiler is not thermal, but rather originating in organic wood derivatives, e.g. amino acids and proteins as well as nitrogen containing process chemicals. One trade-off situation occurs between the nutrient nitrogen in wastewaters and the acidifying NO_X emissions.

Closed-cycle / SOLID WASTE → WATER The quest for the minimum impact/(totally) effluent free/zero discharge/zero effluent etc. pulp and paper mill continues. In short, a decrease in effluents would seem to lead to an increase in solid waste. Millar Western Pulp's solution to this was to transform molten smelt from a small recovery boiler into ingots of mainly sodium carbonate. Before, landfill was the only option, but now research into re-causticising has brought in results.

Biological treatment / ENERGY SOLID WASTE → WATER For BOD reduction, the most effective way has for a while been enhanced biological treatment. This has the consequence of greater energy consumption and more solid waste.

Flue gas cleaning / WATER SOLID WASTE → AIR In flue gas cleaning, fly ash is generated. If wet or semi-dry scrubbing is used, effluent can also result. However, re-circulation and control of this effluent is possible, which leads to elimination of additional effluent discharges.

Energy intensity of paper industry increased / MASS ENERGY AIR → QUALITY Value added products, mechanical pulps, increased speeds give quality but have a general negative effect on mass, energy and atmospheric emissions. The indirect effects of this in the form of cross-industry effects with acidification consequences are hard to allocate.

Sludge incineration / TIME SOIL → ENERGY SOLID WASTE The goal of landfill volume reduction is also pursued by sludge incineration. Incinerating sludge in bark- or wood-fired boilers reduces the amount of hog fuel burned in the boilers and decreases the volume of material going to the landfill. However, it increases the amount of ash produced by the boilers and consequent toxicity problems. A countermeasure is a cinder reinjection program to lower fly ash volume and further reduce the amount of hog fuel requirements.

Lower grammage / QUALITY → MASS The drive towards lower basis weights is seen as environmentally friendly as it lessens raw material use. Less coating through the application of a pigmentised inorganic film decreases the grammage. However, in general lower basis weights cause a problem with optical properties and strength.

Value added Value added in the sense of quality added is a gain, but might cause transfers in all fields. The same applies, if environmental friendliness is seen as quality – which is increasingly true.

Raising PM speeds With paper machine speeds up to 2 500 m/s on the horizon there is a trade-off between time and space, between speed and grammage. Economically motivated, raising speeds has the effect of partially slowing down the increase of filler content, the lowering of basis weights and the closing of effluent systems. The end result may be that these countertendencies counterbalance each other, and that basis weights, energy consumptions and filler contents stay the same. The use of more mineral pigments is further slowed down by the use of recycled fibre. In some papers more than a third of the weight is pigment, which makes incineration difficult. Recently, there have been attempts to recover pigments by dispersion and to feed them back to the paper machine.

Pulp and paper waste / SPACE QUALITY → TIME In general, pulp and paper mills produce high-volume, low-toxicity waste. A problem is the "high moisture/low solids"-consistency of much of the waste, which leads to landfill stability problems and causes inconvenience in waste spreading with bulldozer. Sometimes dewatering is crucial.

Colour problem / WATER TIME → WATER Colour is a danger to aquatic life by interfering with aquatic life in limiting light transmittance. A cross-media transfer occurred for some past solutions to the colour problem: the result was increased discharges of chlorinated organics. For example, sodium hypochlorite aids in solving the colour problem but notably increases e.g. chloroform discharges. Monox-L (hypochlorous acid plus an additive) can be used to replace hypochlorite, chlorine or chlorine dioxide. It reduces dioxin formation but generates chloroform. Sodium hydrosulphite has been used to bleach mechanical pulps (mainly for newsprint and SC paper markets). Hydrosulphite-based bleach systems are now reportedly replacing the traditional use of hypochlorite on cost as well as environmental grounds.

Fly ash treatment / KNOW-HOW → TIME Fly ash in incineration is normally conditioned with water or process effluent at the incineration plant prior to transport or disposal. This is an example of the beneficial utilisation of effluent streams. Controlled landfilling is then often the solution, commonly with pre-treatment to immobilise hazardous and toxic components and bind dust – giving an example of know-how in toxicity control.

7.5 The cases chosen

From the examples highlighted in 7.4 a set of four example cases was chosen. The cases presented below use lessons learned from previous ones – this means that the cases have a cumulative plot. The matrix below (Figure 21), illustrates the concept of the four cases:

1. A case illustrating trade-off between air and solid waste – and cost. This is a pure environmental investment.
2. A case illustrating trade-off between water and solid waste – and cost. This case demonstrates the adaptation of new technology.
3. A case illustrating trade-off between energy and air/water/solid waste – and cost. This is a case where location and infrastructure are important.
4. A case illustrating trade-off between energy, emissions and product/service quality – and cost. Raw material availability is a key issue in this case.

ISSUE \ CASE	Pulp mill	Paper mill	CHP	Multi fuel boiler
Air/solid waste and cost		Scrubber		
Water/solid waste and cost	Closing the loop			
Energy, emission, quality and cost			CHP and NOx	
Energy, emissions, quality and cost		Changes in fibre and product quality		Fuel mix

Figure 21. The case matrix: issues to be presented.

8 Case 1. Air / solid waste and cost

8.1 The specific cross-media problem

The ranking of dealing with solid waste, air and water depends on the priority order in which the limits are set, for example the authorities setting the permit limits and the environmental emphasis in an area and mill technical development.

There are several practical cases that could be used in illustrating the cross-media transfer from air to water and to solid waste including

1. Flue gas cleaning: In flue gas cleaning, fly ash is generated. If wet or semi-dry scrubbing is used, effluent can also result. However, re-circulation and control of this effluent is possible, which leads to elimination of additional effluent discharges.
2. Dust suppression: On some sites of recycling waste storage, dust suppression is of significance. Dust suppression water-sprays at the waste tipping bays can be used. The result: a small increase in water consumption and in the moisture content of the waste. The latter may cause some functional problems in incineration and landfill.
3. Wet scrubbing: Wet scrubbing (washing gases with alkaline solution or slurry) has proven its worth in sulphur dioxide reduction. Increased water consumption follows, and functional difficulties in the shape of sludge disposal problems may follow. This example is analysed in detail as Case 1.

8.2 Practical example of the problem – scrubber

To demonstrate the cross-media problem of air / solid waste and cost, a case, in which a company having a multi fuel boiler invests in a wet scrubber, is analysed.

Scrubbers are widely used to remove dust from flue gas. In a wet venturi-type of scrubber the dust particles in the flue gas smash into small water drops and the resulting dust-droplets are removed from the gas in a cyclone. In some cases in addition to dust also sulphur dioxide can be absorbed into the scrubbing solution. The dust removal efficiency of wet scrubbers varies from 95 to 99 %. The removal efficiency of sulphur dioxide is lower, 80–90 %.

In general, the advantages of wet scrubbers compared with dry scrubbers are:

+ High dust removal efficiency
+ Possibility of flue gas desulphurisation
+ In case of flue gas desulphurisation:
  - Inexpensive desulphurisation chemicals can be used
  - Low consumption of desulphurisation chemicals
  - Possibility of oxidising the formed sulphite to gypsum

The disadvantages of wet scrubbers compared with dry scrubbers are:

– Relatively big and expensive equipment
– Generation of wet sludge
– Water treatment is needed
– Relatively high operational costs

The case

In our case example a bark boiler of a paper mill is studied. The exhaust gases from a bark boiler (45 MW / 60 tons of steam/hour) are first treated with electrostatic precipitator and after that in a scrubber with lime or sodium hydroxide. The problem is the wet waste from the scrubber and its disposal.

It should be noted that neither this case nor the rest of the three cases are universal examples. For example, in this case, in addition to a scrubber, there are several other techniques available, which could be used to decrease acid emissions. The applicability and cost of the techniques depend on the case and the field of industry.

The disposal of the waste from a wet scrubber is costly. The waste sludge contains $CaSO_3$ and $CaCl_2$ or the analogous sodium salts if sodium hydroxide is used as the reagent chemical. The amount of sludge generated is 36 m^3/d.

The scrubber waste is usually disposed of into ponds and landfills. When ponds are used the sludge is not dewatered and lot of space is required. When landfilling alternative is used, the sludge is first dewatered to a concentration of about 55–75 % and then transported to the landfill.

Landfilling

The volume of sludge generated can be reduced to a tenth by thickening and dewatering the sludge.

The sludge from the wet scrubber is first thickened in a gravity thickener. The clear overflow of the thickener is used for chemical preparation and absorption liquid. A centrifuge or a vacuum filter is used in dewatering of the underflow at a concentration of about 30 %. The final concentration would then be 55–75 %. The dewatered sludge to be transported to the landfill is only about 5 m^3/d and the area needed is 4 400 m^2 with the filling height of 4 meters. This area is enough for sludge generated during ten years. Linings and a groundwater monitoring system would be needed. The cost of the landfill improvement would be € 0.15 million.

The landfill would be operated so that only a minor part of the landfill would be in use, filled to its final height and covered. This would minimise the surface run-off from the landfill. The pH of the sludge would be neutral or alkaline which would add an immobilization of heavy metals in the sludge. If more stabilised product is needed, the dewatered sludge is mixed with fly ash in a pug mill, and after that the sludge is transported to landfill. Lime can also be used instead of fly ash, but it is more expensive.

The investment cost for waste slurry treatment would be € 1.1 million, excluding the costs for establishing the landfill.

Below we study trade-offs caused by the scrubber and the disposal of the scrubber waste.

8.3 The decision making situation

From the company's point of view

Background: The company is of medium size and the investment is also of small/ medium size.

Driving force: Existing legislation.

The relevant elements in the decision-making: The price (initial investment cost) of the scrubber matters as do the operation costs. Investments are not done only based on economic rationale, but the references of the supplier and operational accountability of the machinery is important. The scrubber also creates a solid waste problem that has to be anticipated. The disposal requires a place on-site or off-site.

From authorities' point of view

Background: The company may have to apply for a change in its landfilling permits.

Relevant elements in the decision-making: The policy of the authorities as regards reducing of air pollution vs. the waste management policy.

8.4 Choice of methodologies

What is the cross-media situation? Classifying the cases
(w – w – i): Severe cross-media clashes and contrasting effects. Use of resources increases and solid waste is generated. However, emissions to air decrease significantly.

What is our aim? Establishing environmental objectives
The environmental objective is to reduce the (acid) emissions to air while maintaining or decreasing the amount of emissions to water and solid waste. Another objective, which goes hand in hand with the acid emissions, is to prevent health risks and damage to vegetation.

What actions should we take? Measures and sub-measures
The main measure is to build a scrubber. Sub-measures include for example estimation of the emissions to different media with and without the scrubber, cost calculations and analysis of the positive and negative effects of the project. In this example a stressor-impact analysis was made. In addition net present value formulae was used for calculating avoided costs and cost-effectiveness of the measures were calculated.

What are the measurable environmental and economic goals? Baseline and targets
For the baseline situation see Tables 3 and 4. In this case the target can be for example to get the acid emissions clearly below the national limit values, for example in Finland national air quality limit values (Council of State Decisions 480/96 and 481/96; SO_2: health 250 µg/m^3 98 % daily, 80 µg/m^3 daily median during the year, vegetation 20 µg/m^3 yearly average, S deposition 0.3 g/m^3 yearly). Instead of national limits, the limit values can also be site specific or in some countries regional ones.

What investments are needed? Related environmental investment
The studied scrubber and a landfill for the scrubber waste.

8.5 Information requirements

Information listed below is needed for the calculation of emissions and other environmental parameters and avoided cost.

Environmental data
- Raw material consumption
- Energy consumption
- Solid waste generation
- Hazardous waste generation
- Emissions to air
- Emissions to water
- Fate and exposure of emissions (not used in this example)

Economic data
- Total cost of the investment
- Operating cost
- Project lifetime
- Nominal discount rate
- Inflation rate

8.6 Application of the methodology

8.6.1 Information used

Data for the initial case – no scrubber:

Table 3. Environmental data.

Parameter type	Parameter	Unit	Amount
Raw materials	–	–	–
Energy consumption	–	–	–
Solid waste	–	–	–
Hazardous waste	–	–	–
Emissions to air	Temperature	°C	160
	SO_2	t/a	610
	HCl	t/a	50
	Particles	mg/m^3	30*
Emissions to water	–	–	–

* *In this case the particles emissions are not reduced because due to the electrostatic precipitator, the level of particles is very low even before the installation of the scrubber.*

Economic data

There are obviously no investment costs before the investment has been made but there may be some costs that can be avoided by making the investment.

Data for the case "scrubber" – the scrubber with waste handling at a landfill

Table 4. Environmental data.

Parameter type	Parameter	Unit	Amount
Raw materials	$Ca(OH)_2$ (100 %)	kg/d	1 800
	Water	tons/d	180
Energy consumption (with sludge handling)		kWh/d	2 765
Solid waste	–	m^3/d	5
Hazardous waste	–	–	–
Emissions to air	Temperature	C	70
	SO_2	t/a	70
	HCl	t/a	10
	Particles	mg/m^3	30*
Emissions to water	Flow	tons/d	20**
	$CaSO_4$, $CaSO_3$ and $CaCl_2$	kg/d	3 300**

** In this case the particles emissions are not reduced because due to the electrostatic precipitator, the level of particles is very low even before the installation of the scrubber.*
*** Note that these emissions will turn into solid waste after the thickeners.*

Table 5. Economic data.

Factor type	Explanation	Unit	Amount
Total Investment cost	Scrubber	€	3 000 000
Annual Maintenance cost	Electricity, Chemicals, Maintenance Labour, Transportation to landfill	€	270 000
Project lifetime	Time in which the investment cost is expected to be repaid.	years	15
Nominal discount rate	Alternative rate of return had the investment been made elsewhere.	%	8
Infaltion rate	The source is the European average statistic performanceover last 3 years.	%	2.5

8.6.2 Environmental calculations

In this case, the environmental parameters are first divided into stressor categories and potential impact categories (LCA framework). Then, the level of concern per category is analysed. This kind of method has been described in detail for example by Diamond et al. (1999). Stressors and impacts are presented in Table 6.

Table 6. Stressors and impacts.

Stressor categories	Potential impact categories*	No scrubber	Scrubber
	POLLUTION		
Acid emissions	Acid rain	High	Low
Greenhouse gases	Global warming	None	Low (from energy)
	DEPLETION		
Fossil fuel / energy consumption	Primary energy source depletion	None	Low
Solid waste	Land or space consumption	None	Moderate
Water use	Water consumption	None	Low – moderate
Mineral use	Minerala consumption	None	Low – moderate

** Diamond et al. (1999) have also a category called "disturbance" in their list of categories and heat discharges are one stressor in this category.*

Emissions and the used resources can be aggregated and the contributions to the same impact category can often be summed. (Note: in so-called valuation methods even the different impacts are summed.) In this case the SO_2 and HCl emissions are converted to SO_2 equivalents (Table 7). Only the acidification potential of these emissions is taken into account in the conversion factors. Other effects, such as hazardous effects to human health and on plants or corrosive effects are omitted in this example.

Table 7. Conversion of SO_2 and HCl into SO_2 equivalents.

Substance	Factor*	Amount without scrubber	Amount with scrubbeer	t SO_2 eqv/a without scrubber	t SO_2 eqv/a with with scrubber
SO2	1	1 745 kg/d 610 t/a	200 kg/d 70 t/a	610	70
HCl	0.88*	143 kg/d 50 t/a	29 kg/d 10 t/a	44	8.8
			TOTAL	654	78.8

*Lindfors et al. 1995.

Economic calculations

Economic reasoning for the investment is shown in calculating the point at which NPV (Net Present Value) for the investment equals zero. As there is no expectation for potential economic return (income) from the investment this factor in the NPV formula is interpreted as "avoided cost" (or annualised capital charges). The avoided cost could for instance be the potential environmental permit payments or extra bills for waste disposal the company would have to make, if the investment was not carried out. It should be noted that this analysis follows the concept of threshold value, which implies that the smaller the "avoided cost" the lower the threshold for the company to invest. The result tells what amount of threatening costs (that then can be avoided) makes the investment worthwhile.

$$NPV = -\left(\text{Total cost of the investment}\right) + \sum_{i=1}^{n}\left(\frac{\text{income}_i}{\left(1+r\right)^i}\right) = 0$$

The project life for the investment was assumed to be 15 years, which is at Jaakko Pöyry Consulting a conventional value used for the machinery type of investment projects.

The internal rate of return for the investment was set to equal the estimated real interest rate at 5.5 %. The interest was derived with the assumption that a realistic internal interest requirement for a company's own capital would be about 10 % and that for external capital would be about 6 %. Thus a nominal interest rate of 8 % was considered a fair estimate. Of course the actual target rate always depends on for instance the company's performance, type of investment and the general economic situation. The inflation rate was assumed to be at 2.5 %, which is a reasonable estimate considering the recent price developments in the Euro area and the EU inflation target.

The NPV formula was set to equal zero and the avoided cost was assumed to be constant for all 15 payback periods. Thus the following formula was derived:

Avoided cost per annum (constant) =

$$\frac{\text{Total cost of the investment}}{\sum\left(\frac{1}{(1+r)^i}\right)} = \frac{3\ 000\ 000}{\left[\left(\frac{1}{(1+0.055)^1}\right)+\left(\frac{1}{(1+0.055)^2}\right)+\ldots+\left(\frac{1}{(1+0.055)^{15}}\right)\right]}$$

where i = project lifetime (number of years left)
r = interest rate (assumed constant over the project lifetime)

The value for avoided cost was calculated to be € 299 000/a. This means that the total annual costs avoided, when the scrubber has been built (in contrast to if it had not been built), would have to exceed this amount to make the investment economically profitable.

An additional cost is the total annual operating costs. These are costs that specifically accompany the investment made in the scrubber. If the maintenance costs are added to the avoided cost cited above it sums up to € 569 000/a. More than half a million euros total investment and operating costs annually confirm that the scrubber is not a cheap investment.

Value calculations

The concept of value is hard to determine in this case. In the short-term economic point of view, value is gained, if the investment is not made. In both cases (pond and landfill) the sludge is nothing but a cost. The task is to determine, which of these alternatives destroys less value. If the sludge is transported directly to the sludge pond, the sludge becomes a large cost because a large amount of waste is to be stored. If the sludge on the other hand is thickened before transportation to the landfill, costs are not as high as in the pond-alternative. The value of the investment is illustrated in Figure 22.

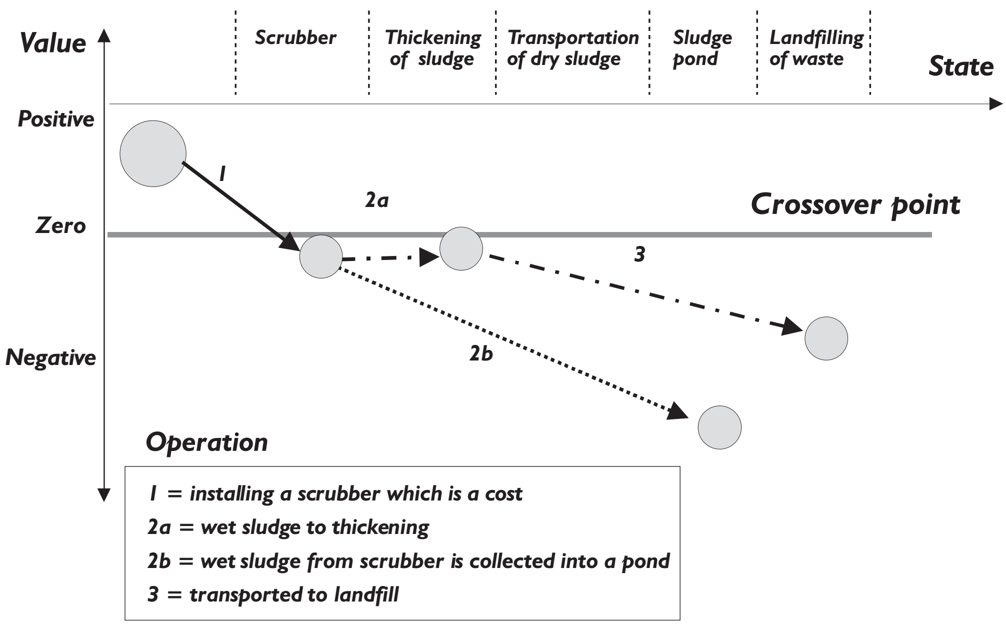


Figure 22. Value diagram for Case 1.

Value for society and environment

The value for the environment and society is basically gained from the important reduction of sulphur emissions. They have to be reduced as early as possible in the process. As far as the other emissions into the environment are concerned, it is important to point out that although other emissions increase, their impact on the environment would seem to be significantly lower than the reduction in sulphur emissions. At least with current knowledge and societal values, the priorisation of the reduction in emissions to air appears to be motivated.

Combination of methods

In this case study the only meaningful way to combine the environmental and economic data is to calculate a cost-effectiveness measure for how much a unit of avoided acid emissions costs the company. However, the reader should be aware that the approach is theoretical and the results illustrative only. The emissions are mainly SO_2 and HCl, which decrease as a result of the scrubber investment. The emissions reductions are quite large: SO_2-emissions are reduced by 89 % and HCl-emissions by 80 % from the starting value.

The cost-effectiveness value can be calculated using the economic numerical sum of annual break-even cost of investment (avoided cost) and maintenance cost. The environmental factor can be either the percentage reduction of an emission or the unit reduction of an emission (e.g. g SO_2 eqv). As a result, two types of values are generated: €/% of emission reduced or €/unit of emission reduced. In this case these results are 0.99 €/kg SO_2 eqv (569 000 €/575 200 kg) and 6 466 €/% (569 000 €/88 %). Cost-effectiveness analysis can be used as a supportive tool in investment alternative comparison provided that the costs have been properly allocated.

8.7 Conclusions

Figure 23 below summarises the initial objectives and action plan for the case.

Cross-Media Clashes		Type	Environmental objectives	Measure	Sub-Measure	Baseline 200X	Target 20YZ	Related Enviro-investment
SEVERE CLASH / NEGATIVE	acidic emissions (i) emissions to water (w) solid waste (w)	iww	To reduce the acidic emissions to air while maintaining or deccreasing the amount of solid waste and emissions to water	To build a scrubber	Estimation of the emissions to different media with and without the scrubber, cost calculations and analysis of positive and negative effects.	SO_2 610 mg/m^3 HCl 50 mg/m^3 Particles 30 mg/m^3	Get acid emissions clearly below national target levels	The scrubber and a landfill for scrubber waste

Figure 23. Cross-media action table.

Advantages and disadvantages:

- \+ SO_2 emissions decrease by 89 %
- \+ HCl emissions decrease by 80 %
- – Generation of solid waste 5 m^3/d
    - • Generation of wastewater 20 tons/d

- Generation of $CaSO_4$, $CaSO_3$ and $CaCl_2$ 3 300 kg/d

– Increased energy and raw material consumption
– Fairly costly investment and expensive to maintain

READING A RUGPLOT

The cases are illustrated by so-called rug plots (as in Figure 24). These have several characteristics which make them valuable for cross-media assessments, e.g.

- they give a quick visual overview of the complex web of dimensional pairwise clashes (the plot should have as much white and as little dark grey as possible)
- they enable us to pairwise comparisons of key dimensions in one single structure

What is a rugplot? It is a matrix of individual plots; one first defines which are the dimensions one wants to match in pairwise comparisons (in Figure 24, dust, acid emissions and cost vs. solid waste and resource consumption, which results in a 3*2-matrix). The pairwise matches happen as they should in any x-y-matrix: first dust vs. solid waste, then dust vs. resource consumption and so on.

What patterns can occur in a rug plot? Basically, those listed in Figure 24:

- with DARK GREY we encode a pattern where the end state is a deterioration in one or both dimensions, while no dimension improves
- with LIGHT GREY we encode a cross-media clash (one dimension improves, the other deteriorates) or a situation where the changes in both dimensions are below a certain significance threshold
- with WHITE we encode a pattern where the end state is an improvement in one or both dimensions (the axes are arranged so that this visual pattern emerges), while no dimension deteriorates

Thus, quick pairwise matches and an instant colour "feel" of the complex situation.

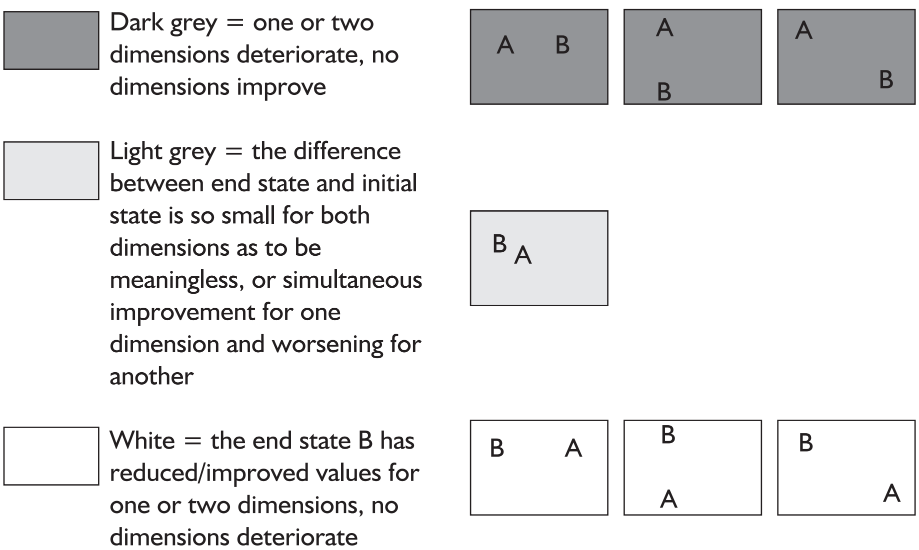


Figure 24. The rug plot matrix pattern.

Figure 25 shows a rug plot matrix consisting of selected main parameters of the case. The first box on the left shows the situation of dust versus solid waste. Because in this case the dust emissions stay at constant level while the amount of solid waste increases, the colour of this comparison box is dark grey.

In the second box on the left, acid emissions are compared to solid waste. At the initial state (A) the amount of solid waste is low whereas there are lots of acid emissions. When a scrubber is installed (B), the amount of solid waste increases while acid emissions decrease. Because there is both a positive and a negative change, the colour of the comparison box is light grey. The other boxes follow the same logic.

As can be seen from Figure 25 the investment increases generation of solid waste and resource consumption. This in turn increases the landfill costs, water costs, energy and raw material costs. Dust emissions stay at constant level, in this case, because due to the electrostatic precipitator, the level of particles in flue gas is very low even before the scrubber installation. Only SO_2 and HCl emissions are reduced but even boxes in the rug plot matrix concerned with these emissions are coloured light grey (which implies a cross-media clash, i.e. one dimension improves, the other does the opposite). Despite these apparent shortcomings the scrubber is still a worthwhile investment. The answer to this seemingly paradoxical situation is the quality of the emissions. Use of resources, solid waste and wastewater problems are in this case easier to tackle and less commonly valued relative to the problems created by acid emissions. Therefore, being able to control these emissions is worth a trade-off in easier problems.

SPECIAL LESSON FROM CASE 1:
USE COMMON SENSE IN EVALUATING A TRADE-OFF
Don't follow any method slavishly. If a result is desirable, and the trade-off is worth it for reasons of common sense and case specifics, go for it.

MESSAGE
IPPC is not easy, even for one piece of equipment.

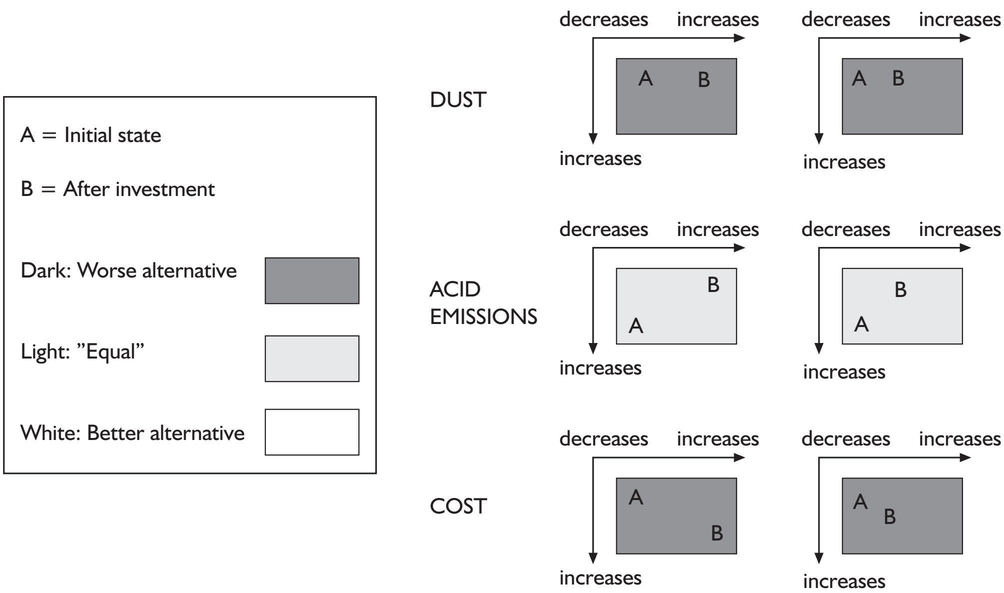


Figure 25. The rug plot matrix for Case 1.

Case 2. Water / solid waste and cost

9

9.1 The specific cross-media problem

This problem is a general one, common to several processes for treating wastewaters. In these processes the contaminants in the water are in some way transferred into solid particles, which are collected into sludge, finally ending up as solid waste. Some typical examples:

1. **The common primary treatment, or sedimentation.** Fibres and other solids are mechanically removed from the wastewater, resulting in a fibrous sludge. This "waste" can sometimes be recycled to the production, which in fact is a "final solution" of this problem. In other cases the sludge is used in some other type of recycling, incinerated (perhaps resulting in air pollution), or landfilled.
2. **Biological treatment.** Organic matter, dissolved and particulate, in the wastewater is decomposed by micro-organisms, forming an excess of organisms – the biological sludge. These solids, after dewatering, are finally dealt with by e.g. incineration, composting (to create a soil product) or landfilling.
3. **Chemical treatment.** Chemicals are added to the wastewater, to enhance the settling of fine particles and/or to precipitate dissolved matter. The final disposal of the sludge, formed in this process, is often more troublesome, compared to the sludge issue in 1 and 2 above, due to its higher mineral and/or water content. Methods similar to the biological sludge treatment are often used for the disposal, although incineration to a smaller and landfill to a larger extent.
4. **Closed cycles, i.e. increased reuse/recycling of water in pulp or paper machine systems.** The purpose may be primarily to reduce water consumption, but in a wider perspective also to reduce the discharge of pollutants. This latter reduction is often less troublesome and cheaper, if the wastewater flow is first reduced. In any case, the recycling of water leads to increased solids concentration in the circulating water, with the need, at a certain level, to remove solids from the water. This may lead to a solid waste problem similar to some of those described in 1–3 above. This example is analysed in detail as Case 2.

9.2 Practical example of the problem

As an example we choose a case from CTMP (Chemithermomechanical Pulp) production, where a water system very near a closed cycle exists. The wastewater, with a low flow due to a high rate of recycling, contains dissolved organic matter, dissolved from wood in the pulping process, and dissolved inorganic matter, residues of the pulping chemicals. There are two potential methods to treat the wastewater. The traditional way is to use biological water treatment. Another, less applied method is evaporation of the wastewater, so called Zero Effluent process.

The advantages of the "Zero Effluent Process" and similar processes, compared to the conventional process, are:

+ Very low water consumption
+ Very high removal of organic matter
+ Lower total generation of solid wastes in case the evaporation residue can be recycled
+ The solid residue is mainly harmless. A potential exists in some cases to re-use this as a pulping chemical.

Disadvantages are:
– Higher investment cost
– At present much less experience, implying potential safety and functionality risks
– If recycling of the solid residue is not possible, the solid waste problem remains
– In the case of sulphur containing chemicals in the CTMP pulping, another cross-media effect may be the emission of sulphur dioxide from the incineration of the concentrate.

Operation costs of the Zero Effluent and the conventional process have been reported as comparable.

The case

In this case a mill producing 400 ADt/d CTMP plans to invest either to a biological wastewater treatment plant or to a Zero Effluent system. The effects of the two investment alternatives are compared.

Evaporation
The wastewater can be evaporated to give high concentration residue of dissolved matter. The evaporation process is illustrated in Figure 26. The evaporated water is condensed, giving high purity water that can be recycled in the process. The evaporation residue is incinerated, which destroys the organics and leaves the inorganic matter in a solid form. This treatment may result in COD removals of 95–98 %.

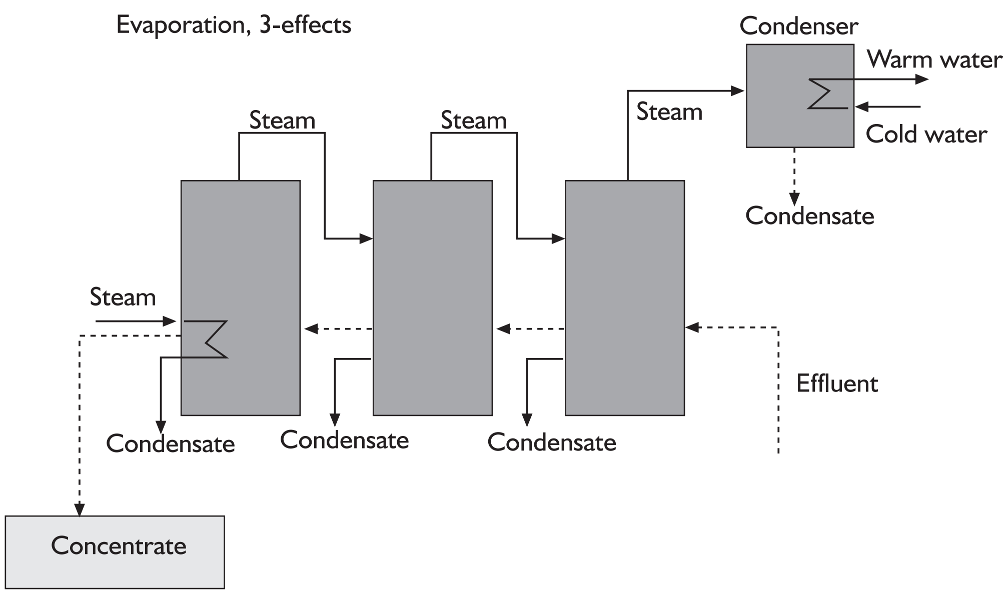


Figure 26. Evaporation process.

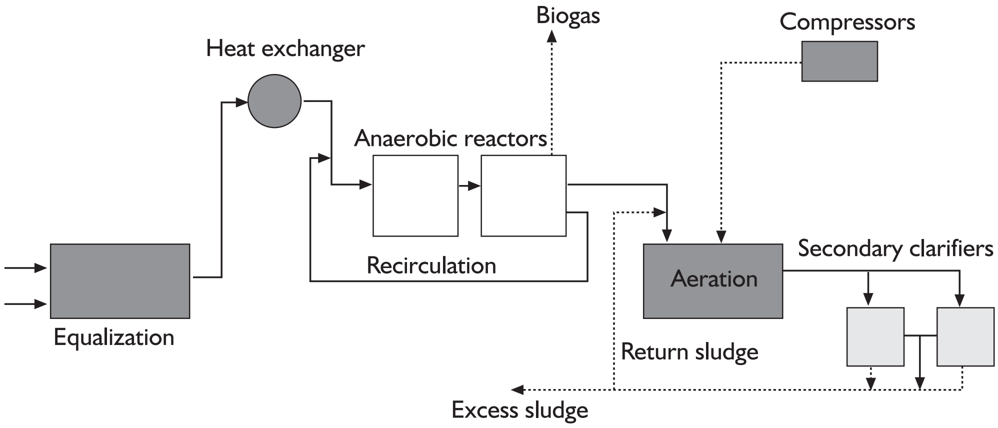


Figure 27. Two-stage biological treatment, anaerobic reactor and activated sludge treatment.

The incinerated solid matter consists largely of soda ash and it has been reported that it can also be reused as a pulping chemical. The potential of the solid waste recycling is higher in the case of non-sulphur chemicals in the CTMP pulping, compared with sulphur containing chemicals. However, the chemicals recycling process requires such a high machinery investments, that this alternative is not feasible in this case.

Biological treatment
The main competing, "conventional" technology for reducing COD emissions from CTMP mills is biological treatment of the wastewater (extensively applied), possibly followed by tertiary treatment in the form of chemical flocculation (less common). However, in this case the effluent is so concentrated that also an anaerobic pre-treatment is needed. The biological treatment process is illustrated in Figure 27.

9.3 The decision-making situation

From the company's point of view

Background: This is a large company and the investment is new (both technologically advanced and otherwise significant) and significant financially.

Driving force: The mill is lacking the equipment for extensive water treatment and also the space to place it in. Thus the solution is to minimize wastewater.

The relevant elements in the decision-making: The price (initial investment cost) and the operation costs of the equipment. Because the investment is into new technology the company is about to take a conscious risk. References of the supplier and operational accountability of the machinery are equally important. Land use is also an issue in this case.

From authorities' point of view
Background: The process is new – is there a safety hazard?

Relevant elements in the decision-making: The reliability of the equipment suppliers, the experience gathered, the results hoped for, the possibility to encourage environmental innovations.

9.4 Choice of methodologies

What is the cross-media situation? Classifying the cases
(i – i – w): Severe cross-media clashes and/or contrasting effects exist. The evaporation alternative has very low water consumption and very high removal of organic material from the effluent. However, it generates more solid waste than the biological treatment alternative. In addition, because the evaporation alternative is more expensive and there is currently little experience of its use, it is less attractive from the economic point of view.

What is our aim? Establishing environmental objectives
The environmental objective is to reduce the organic emissions to water recipients, while maintaining or decreasing the amount of other emissions and solid waste.

What actions should we take? Measures and sub-measures
The main measure is to build either a biological wastewater treatment plant or a Zero Effluent evaporation system. Sub-measures include for both of the alternatives estimation of the emissions to different media, cost calculations and analysis of the positive and negative effects of the project. In this example the avoided cost was calculated for both alternatives and their cost effectiveness was also analysed.

What are the measurable environmental and economic goals? Baseline and targets
In the baseline situation the mill, which produces 400 ADt CTMP a day, has water consumption of 2–7 m^3/Adt and COD emission without treatment 130 kg/ADt. The target is to get the organic emissions clearly below the mill specific emission limits.

What investments are needed? Related environmental investment
Either the biological wastewater treatment plant or the evaporation system is needed.

9.5 Information requirements

Information listed below is needed for the calculation of emissions and avoided cost.

Environmental data
Raw material consumption
Energy consumption
Solid waste generation
Emissions to water
Fate and exposure of organic matter (COD) (not used in this case)
Economic data

Total cost of the investment
Maintenance cost
Project lifetime
Nominal discount rate
Inflation rate

9.6 Application of the methodology

9.6.1 Information used

Some typical data for a practical case are presented.

• Production size	400 ADt/d CTMP
• Water consumption = Wastewater discharge	2–7 m^3/ADt
• COD emission before treatment	130 kg/ADt = 52 t/d

Data for evaporation

COD emission after treatment	2.5–6.5 kg/ADt	1–2.5 t/d
Solid waste generation	60 kg/ADt	24 t/d, as dry solids

The solid waste consists of inorganic salts. These salts are to a main part easily soluble in water (soda ash). If this waste shall be landfilled, special precautions have to be taken to avoid dissolution. However, with this type of process, a primary aim must be either recycling the chemical to the process or selling the material to other users.

The evaporation of CTMP filtrate was dimensioned for 4.5 m^3/ADt (range 2–7) or about 20 l/s incoming effluent. The investment for the plant is 6.3 million Euros and the operating cost about € 0.65 million annually. The cost of low-pressure steam (included in the operating costs) is 4.9 €/ton (estimate).

It is supposed that the concentrate from the evaporation plant is burned in a bark boiler. If the evaporation plant would need a separate incineration plant the investments would be remarkably higher and the option would not be feasible. The economic data for evaporation alternative is displayed in Table 8.

Table 8. Economic data for evaporation.

Factor type	Explanation	Unit	Amount
Total investment cost	Evaporation equipment	€	6 300 000
Annual operating costs	Electricity, maintenance, labour	€	650 000
Project lifetime	Time in which the investment cost is expected to be repaid.	years	15
Nominal discount rate	Alternative rate of return had the investment been made elsewhere.	%	8
Inflation rate	The source is the European average statistic performance over the last 3 years.	%	2.5

Data for biological wastewater treatment

The COD load to the effluent treatment is 52 t/d and the BOD load is 22 t/d. The effluent is so concentrated that an anaerobic pre-treatment, before the activated sludge plant is needed.

COD emission after treatment (removal approximately 85–90 %)	10–12 kg/ADt
Solid waste generation	6.6 t/d, as dry solids

The investments for two-phase biological treatment (anaerobic reactors and activated sludge plant) are 5.3 million Euros and the annual operating costs are 0.49 million Euros.

It should be noted that, if the mill would be integrated, there would also be effluent from the paper machines, which would dilute the effluent from the CTMP plant. Then only an extended aerated activated sludge plant (no two phase process) should be enough and the investment would be smaller for the CTMP plant. Economic data for the biological waste water treatment is displayed in Table 9.

Table 9. Economic data for biological waste water treatment.

Factor type	Explanation	Unit	Amount
Total investment cost	Two-phase biological treatment	€	5 300 000
Annual operating costs	Electricity, chemicals, maintenance, labour	€	490 000
Project lifetime	Time in which the investment cost is expected to be repaid.	years	15
Nominal discount rate	Alternative rate of return had the investment been made elsewhere.	%	8
Inflation rate	The source is the European average statistic performance over the last 3 years.	%	2.5

9.6.2 Calculations

Environmental calculations

In this case there is a severe cross-media clash between COD emissions, solid waste and energy consumption. Table 10 summarises the situation. In a decision-making situation, it is important, especially in this case, to consider the local environmental conditions. In other words, which of the parameters, COD or solid waste, causes less negative effects on the local environment.

Table 10. Environmental results of the investment alternatives.

	Evaporation	Biological treatment	Difference
COD	1.0–2.6 t/d	4.0–4.8 t/d	Biological is about two to four fold higher than evaporation
Solid waste	24 t/d	6.6 t/d	Biological is over 70 % lower than evaporation
Chemicals	Minor amounts of chemicals for washing purposes	• N-nutrient, (urea): 1.9 tons/d • P-nutrient (phosphorus acid): 0.8 tons/d • Polymers: 0.04 tons/d	
Electricity	3 600 kWh/d	9 400 kWh/d	Biological is over 160 % higher.
Heat	440 GJ/d	0	Biological does not need heat at all.

Evaporation

The avoided costs were calculated according to the following equation using the data from Table 8:

$$\text{Total avoided cost per annum} = \frac{\text{Total cost of the investment}}{\sum\left(\frac{1}{(1+\text{r})^{i}}\right)} + \text{operating costs.}$$

The result was € 1.28 million.

Biological treatment

The avoided costs were calculated according to the following equation using the data from Table 9:

$$\text{Total avoided cost per annum} = \frac{\text{Total cost of the investment}}{\sum\left(\frac{1}{(1+r)^i}\right)} + \text{operating costs.}$$

The result was € 1.02 million, which indicates that biological treatment would be the financially preferable alternative.

Because of a risk factor (new technology) the interest rate used for the evaporation alternative calculations could be higher than that used for the biological treatment alternative. However, the cost gap between the two methods would only be widened, if a higher interest rate would be applied.

Value calculations

In this case the value is primarily determined from the investment costs. The zero-effluent process, evaporation appears to be less interesting from the economic point of view. Secondly, the value is affected in both alternatives by how the concentrate / sludge from these processes are treated. In the zero-effluent process the possible value can be destroyed, if the evaporation concentrate is not recycled but landfilled. When biological treatment is used, the sludge can either be incinerated or landfilled. The landfill option increases costs more than incineration. The formation of value is illustrated in Figure 28.

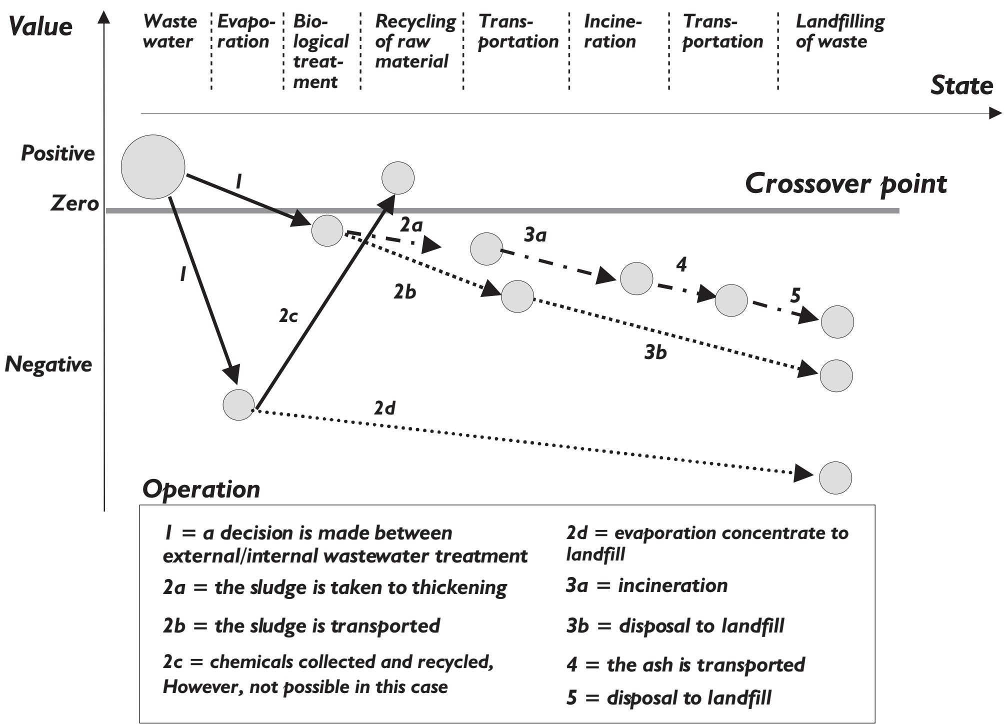


Figure 28. Value diagram for Case 2.

Value for society and the environment

The zero-effluent process is at the very least an attempt at environmental innovation with a positive profile, especially if recycling of the chemicals is possible. This alone should make it of value also to society.

Combination of methods

It is possible to calculate cost-effectiveness figures on the basis of emissions and waste created at the mill site. Here two kinds of illustrative examples are explained. The first one shows the relationship between the total investment cost and unit of water pollution (in this case of chemical oxygen demand, COD). The second one shows how much the gain achieved by jumping from the less effective method to the more effective method costs.

The starting point for COD-emissions is 18 200 t/a (52 t/d*350 days). The evaporation method abates emissions (on average) by 17 500 t/a and the biological treatment abates them by 16 800 t/a. However, the investment and operation costs for the evaporation alternative are greater than those for the biological treatment alternative. The concept of avoided cost used earlier is used also here and interpret it as the average avoided cost of the investment. This can be calculated for both cases separately, using the emissions at the starting point as reference values. In this analysis both of the measures are thus compared to the situation where no environmental investments have been made.

$$\text{Cost per unit of COD abated} = -\left(\frac{\text{Avoided cost (€/a)}}{\text{Annual amount of COD abated (t/a)}}\right).$$

The cost in the case of evaporation is 73 €/ton of COD abated and in the case of biological treatment 61 €/ton of COD abated.

Another perspective is to look at the difference in cost relative to the difference in emission reduction. In this case the cheaper alternative (in this case the biological treatment) is the point of reference. If the company would instead invest in the more expensive alternative, they would get less emissions.

$$\text{Cost per additional unit of COD abated} = \left(\frac{\text{Avoided cost}_{\text{biological}} - \text{Avoided cost}_{\text{evaporation}}}{COD_{\text{biological}}(\text{t/a}) - COD_{\text{evaporation}}(\text{t/a})}\right)$$

$$= \left(\frac{1020000 - 1280000}{1540 - 630}\right) = -286 \text{ €/t.}$$

If the company invests in evaporation instead of biological treatment, each additional ton of COD abated costs 286 €.

It is crucially important to the interpretation of cost-effectiveness results that the costs have been properly allocated. In this case we have allocated the entire investment costs on COD emissions. Of course there are other emissions as well and the example results should be regarded as illustrative and applicable to this particular case only.

9.7 Conclusions

Figure 29 below summarises the initial objectives and action plan for the case.

Cross-Media Clashes		Type	environmental objectives	Measure	Sub-Measure	Baseline 200x	Target 20YZ	Related enviro-investment
SEVERE CLASH / POSITIVE	emissions to water (i) water consumption (i) solid waste (w)	iiw	To reduce the emissions to water while maintaining or decreasing the amount solid waste. This should be done in an economically efficient way.	To build either a biological waste-water treatment plant or Zero Effluent evaporation system.	Estimation of the emissions to different media in the alternatives, cost calculations and analysis of the positive and negative effects of the project.	The water consumption is 2–7 m^3/Adt and COD emissions without treatment are 130 kg/Adt.	To get the organic emissions clearly below the mill specific emission levels.	Either the biological wastewater treatment plant or an evaporation system is needed.

Figure 29. Cross-media action table.

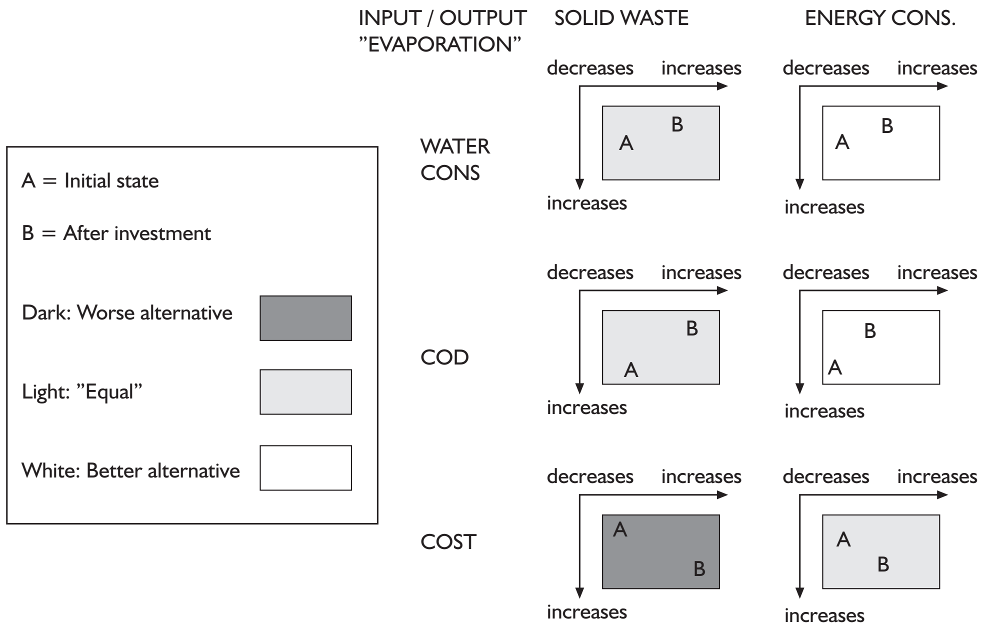
Advantages and disadvantages:

As it has already been shown in the results, there is a definite clash in this case. It is a matter of preference whether water emissions or solid waste is a point to focus on. Referring to the avoided cost calculations the economically preferred alternative would be the biological treatment. However, the value of environmental innovation, especially in an area of high significance, should not be discounted.

Figure 30 shows a rug plot matrix consisting of selected main parameters of the case. For detailed explanations on these matrixes, please see Chapter 8.7 and Figure 24. The studied rug plot contains a two level comparison. First both investments are compared to "initial state", or a situation, where there is neither evaporation nor wastewater treatment system. This comparison is marked with A and B letters on the investment alternatives' rug plots. In the second comparison, the investment alternatives are compared between each other. This comparison is indicated with colour codes.

For example, the first small plot on the right of the top row of "Evaporation" rug plot shows the comparison of water consumption versus energy consumption at the two levels. At the first level the mutual location of letters A and B is focused upon. In the initial state "A" the process consumes more water but less energy than in case an evaporation investment was made, state "B". At the second level the colouring of each box tells the effectiveness of the evaporation method compared to the alternative of biological treatment. The white colouring of the small plot shows that from the point of these two parameters the evaporation alternative is better than the biological treatment alternative.

No clear answer can be given for which of the two options is better. If innovative approach is valued, evaporation might be chosen. Biological treatment, on the other hand, is a technique with lots of operational experience.



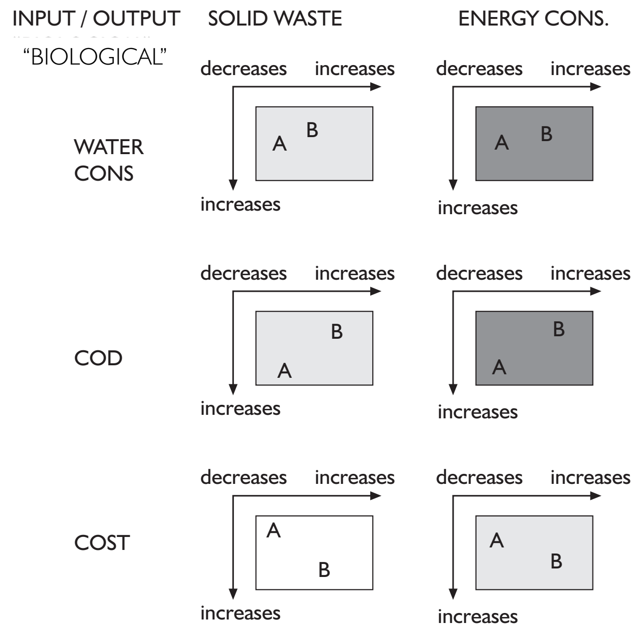


Figure 30. The rug plot matrix for Case 2.

SPECIAL LESSON FROM CASE 2:
THE VALUE OF ENVIRONMENTAL INNOVATION
For the company, its embarkment on a path of environmental innovation can be pondered also e.g. in environmental image. However, the real focus is on the authorities: should there be special allowances for environmental innovation activities, especially ones with wide potential positive ramifications?

MESSAGE
Optimisation of one parameter may just be a transfer from one pocket to another

Case 3. Energy / emissions and cost

10

10.1 The specific cross-media problem

1. One cross-media case involving energy, emissions and cost is a biological treatment plant (energy, soil, water, cost). For BOD reduction, the most effective way has for a while been enhanced biological treatment. This has the consequence of greater energy consumption and more solid waste.
2. Energy efficiency is the key issue when considering the environmental performance of energy production and use. It affects several factors such as utilisation of natural resources, the amount and quality of emissions in atmosphere and also the amount and quality of by-products or solid waste. On the other hand, energy efficiency is also a key issue for the economical performance. This example is analysed in detail as Case 3.

10.2 Practical example of the problem – to CHP or not to CHP

To demonstrate the cross-media problem of energy, emissions and cost, a case in which a CHP (combined heat and power) plant is compared to a traditional condensing power plant is presented. In a CHP plant, all steam generated in the boilers passes to generators for electricity generation. Steam can be extracted at points on the turbine and/or from the turbine exhaust as backpressure steam and used to supply heat for industrial processes or district heating. The electricity and heat are both main products of the plant.

According to the Reference Document on BAT in the Pulp and Paper Industry (Joint Research Centre 2000) the energy efficiency of CHP is in the range 80–93 %, whereas the energy efficiency of separate electricity production is about 40–45 %. The rest is lost as low temperature waste heat. This means that cogeneration of heat and power saves fuel in comparison to separate production of heat and power. CHP produces benefits in the form of a corresponding decrease in the amounts of NO_X, SO_2, particulates and CO_2. For example, according to Joint Research Centre, at the maximum overall thermal efficiency of 93 %, the carbon dioxide emissions decrease by 46 %, NO_X emissions by 38 %, and SO_2 emissions up to 100% compared to conventional power generation with the efficiency of 38 %. When costs of avoiding pollutant emissions are calculated, large-scale cogeneration is one of the cheapest methods of pollution abatement, in addition to being a method of energy conservation (Finnish Expert Report 2001).

The case

As said above, when energy is produced from fossil fuels, the plants with highest energy efficiency are also the ones with least emissions. This means that there is no cross-media problem between energy efficiency and emissions.

However, when costs are added to the equation, the situation gets more complicated. CHP plants convert 40–70 % of the energy input into heat and 20–45 % into electricity depending on the CHP system. For cogeneration to compete successfully in the marketplace, a high price of electricity and a big enough local heat demand are required. This means that the production of both heat and power must be profitable. If the local heat load is large enough, cogeneration often also saves money. For a small heat demand, the plant size remains under the limit of economic competitiveness (Finnish Expert Report 2001). In case the electricity price is low compared to the fuel prices, it is not economically feasible to produce electricity in a combined heat and power plant. Even if the heat produced could be sold at a reasonable price, the electricity price can be lower than the production costs making the whole power plant unprofitable.

In making comparisons between separate condensing power generation and cogeneration of heat and power, the problem of assigning the investment, fuel and other operating costs to the two marketable products arises.

There is recent research work done on a regional energy system in a Finnish city (Jyväskylä) and the results are used as the basis for our case study. The research was carried out by the School of Business and Economics at University of Jyväskylä and by Fortum Power and Heat Oy. The studied city has about 80 000 inhabitants. The total annual energy consumption of the region is about 3 300 GWh. About half of this is used for heating buildings and a third is consumed by industry. The heat and power production is largely based on local fuels, mostly peat (44 %) and partly wood-based fuels. Imported electricity contributes about 10 % to the primary energy procurement. The energy consumption of the analysed systems sums up to 2 000 GWh, when the energy consumption of transport and hydroelectric power generation are excluded from it. Imported electricity has been taken into account in the electricity production.

Currently there exists a CHP plant, which delivers electricity to the city and to a steel industry plant. It also delivers heat to the city and steam to a paper mill. The Jyväskylä research has compared several alternatives and their environmental and socio-economic effects. Our case study compares the alternatives of the current CHP production and that of separate production. In the separate production alternative heat is produced in a plant that uses a fuel mix identical to the current plant and electricity is produced in a condensing power plant that uses coal as fuel. The steel plant and the paper mill have steam boilers that are operated with peat and light fuel oil.

10.3 The decision-making situation

From the company's point of view

Background: The company is large. The investment is strategically and financially significant.

Driving force: The electricity prices (and trying to forecast their trends) are decisive. (The liberalisation of the electricity markets has made the forecasting even more challenging than before.)

The relevant elements in the decision-making: The demand for heat and electricity has to be estimated. The fuel prices and their estimated future developments are taken into account. The company also has to take into account that once a CHP plant has been made it cannot easily be converted to other kinds of electricity production (the system is fairly rigid once it is in place).

From authorities' point of view

Background: The (short) history of CHP policies in Europe can be said to be highly varied and perhaps even colourful. Measures on encouragement of investments in CHP are prepared in Brussels, while authorities around the continent grapple with national and local level issues.

Relevant elements in the decision-making: To name but a few, what are the goals for electricity production? Is there a strategy for fuel mixes? What is the relationship between national and local authorities?

10.4 Choice of methodologies

What is the cross-media situation? Classifying the cases

(i – i – w): Potential for severe cross-media clashes and contrasting effects. CHP consumes less fuels and generates less emissions to air than what separate heat and power production does. However, this investment alternative is more profitable only in some situations: there has to be sufficient demand for heat produced and the relationship between fuel and electricity prices must be within the right tolerance.

What is our aim? Establishing environmental objectives

The environmental objective is to produce heat and power with as little emissions as possible.

What actions should we take? Measures and sub-measures

The main measure is to build either a CHP-plant or separate power plants for electricity and heat production. Sub-measures include estimation of the emissions to different media, cost calculations and analysis of the positive and negative effects of the project for both of the alternatives.

What are the measurable environmental and economic goals? Baseline and targets

The target is to produce 2 000 GWh of energy (heat and power) with maximal efficiency.

What investments are needed? Related environmental investment

No separate environmental investments here. A whole plant is built.

10.5 Information requirements

Information listed below is needed for the calculation of emissions and other environmental parameters and avoided cost.

Environmental data
- Fuel consumption
- Solid waste generation

- Hazardous waste generation
- Emissions to air
- Fate and exposure of emissions (not used in this case)
- Economic data

Total cost of the investment
- Maintenance cost
- Project lifetime
- Nominal discount rate
- Inflation rate

10.6 Application of the methodology

10.6.1 Information used

Data for the case with combined production (CHP)

Environmental data for the CHP case is provided in Table 11 and economic data in Table 12.

Environmental data

Table 11. Environmental data for combined production.

Parameter type	Parameter	Unit	Amount
Emissions to air	CO_2	tons/a	600 000
	NO_X	tons/a	1 380
	SO_2	tons/a	1 640
	TSP	tons/a	100
Fuels needed for power and heat		TJ/a	7 344

Table 12. Economic data for combined production.

Factor type	Explanation	Unit	Amount
Total investment cost	Power plants and infrastructure for delivery of power	€	219 000 000

Data for the case with separate production

Environmental data for the case with separate production is provided in Table 13 and economic data in Table 14.

Environmental data

Table 13. Environmental data for separate production.

Parameter type	Parameter	Unit	Amount
Emissions to air	CO_2	tons/a	870 000
	NO_X	tons/a	1 680
	SO_2	tons/a	1 780
	TSP	tons/a	110
Fuels needed for power and heat		TJ/a	9 252

Economic data

Table 14. Economic data for separate production.

Factor type	Explanation	Unit	Amount
Total investment cost	Power plants and infra-structure for delivery of power	€	286 000 000

10.6.2 Calculations

Environmental calculations

In this case the comparison of emissions is easy – CHP wins over separate production for all parameters (Table 15).

Table 15. Comparison of the emissions.

Type of emissions	Co-generation	Separate production	Percentage change from separate production to CHP
CO_2 tons/a	600 000	870 000	Decreases approx. – 30 %
NO_x tons/a	1 380	1 680	Decreases approx. – 15 %
SO_2 tons/a	1 640	1 780	Decreases approx. – 10 %
TSP tons/a	100	110	Decreases approx. – 10 %
Fuel amount TJ/a	7 344	9 252	Decreases approx. – 20 %

Economic calculations

The investment costs given are for the entire system and should be separated for units before further financial assessment of the alternatives. Table 16 shows the comparison of the investment costs in the two alternatives.

Table 16. Comparison of the total investment costs.

Type of cost	Co-generation	Separate production	Percentage change from separate production to CHP
Total investment cost, e million	219	286	Decreases approx. – 23 %

Value calculations

The value in this case is affected by several different factors. First, the current fuel prices determine, whether the project is cost-effective in the short term or not. Then, the time element including projected electricity prices needs to be taken into account. The liberalisation of the electricity markets has made the forecasting even more challenging than before. The second factor affecting the value is the ratio between electricity and heat demand in the area. If these two supplies are not in balance the project rapidly becomes uneconomic. Most commonly the favourable balance is achieved, when there is an industrial user of heat or large enough private heat demand located in the area. The third factor of importance is the availability of an existing district heating system. The construction of such systems demands large investments and may have a decisive impact on the CHP project. In the case of Jyväskylä town, the "historical" developments in the town's heating system favour district heating (and CHP). Most of the houses have had central heating systems, which have been relatively easy to link to a district heating network. The value formation is displayed in Figure 31.

Value for society and environment

In this case "local" fuels (peat, wood) suitable for CHP are available. The use of local fuels has a positive effect on the local employment. So, if a change from one concept of generating energy to another is done the employment is also affected. A radical change in the fuel mix (to contain other fuels than the local ones), can disturb the network for collection, transportation etc. and can have a negative effect on the employment rate in the area concerned.

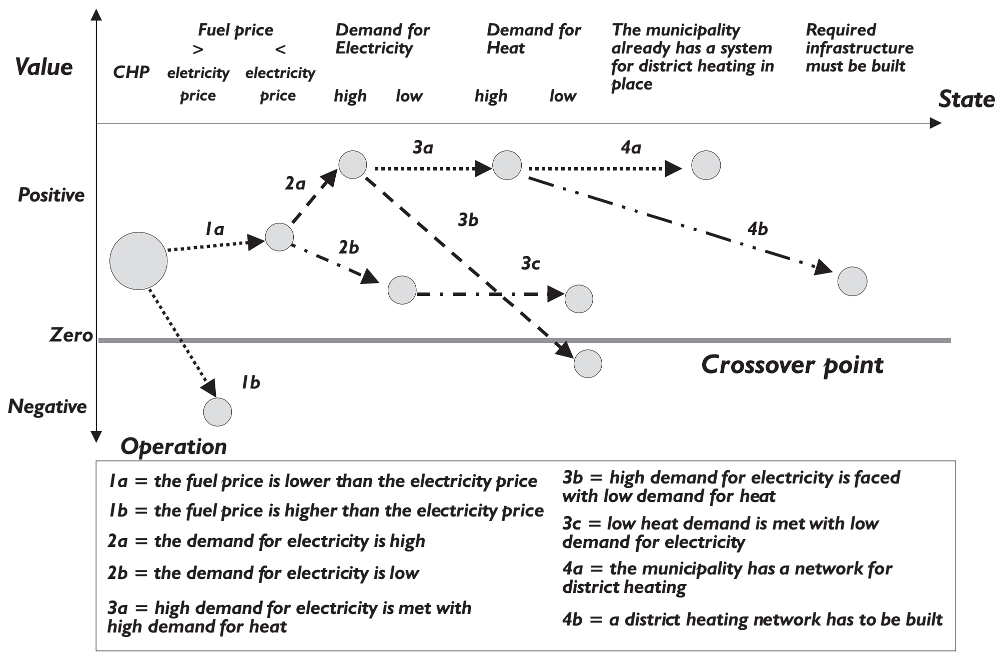


Figure 31. Value diagram for Case 3.

10.7 Conclusions

Figure 32 below summarises the initial objectives and action plan for the case.

	Cross-Media Clashes	Type	Environmental objectives	Measure	Sub-Measure	Baseline 200X	Target 20YZ	Related Enviro-investment
SEVERE CLASH / POSITIVE	emissions to water (i) water consuption (i) economic (0/w/i)	(poten-tially) iiw	To produce heat and electricity with the minimal environmental impact. An aim is also to be ecomomically efficient in the production.	Build a combined heat and power plant.	Estimation of the emissions to different media, cost calculations and analysis of the positive and negative effects of the project.	The emission levels in separate production.	To reduce the emissions and improve the efficiency of energy production.	The main investment is the selected power plant type, separate production or CHP.

Figure 32. Cross-media action table.

Advantages and disadvantages:

+ Higher energy efficiency
+ Considerably lower emissions
– Requirement of demand for both electricity and heat
– Unprofitability at certain fuel and electricity price levels

Figure 33 shows a rug plot matrix consisting of selected main parameters of the case. For detailed explanations on these matrixes, please see Chapter 8.7 and Figure 24. In this case separate heat and power production are marked as the initial state, and CHP describes the situation after the investment. The rug plot below gives a clear message: CHP is a better alternative in what comes to emissions to air and fuel consumption, whereas the cost situation is completely time and case dependant.

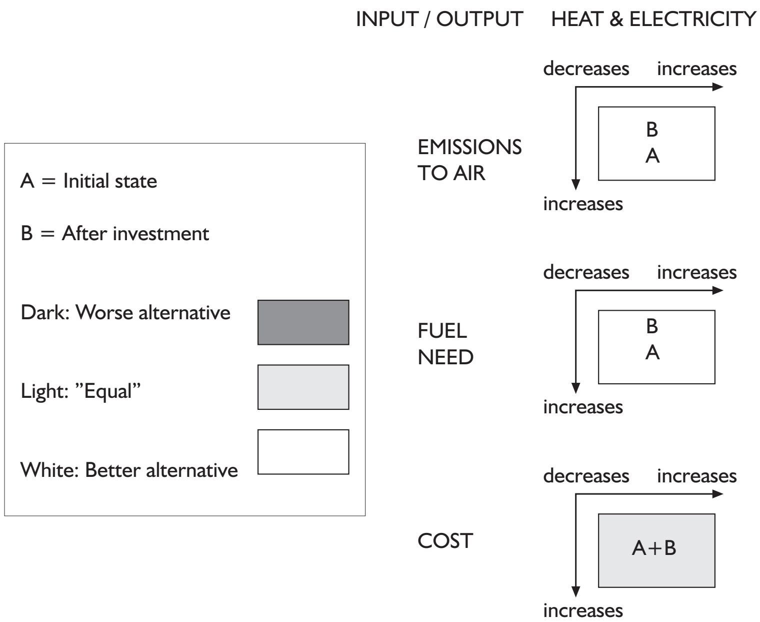


Figure 33. The rug plot matrix for Case 3.

SPECIAL LESSON FROM CASE 3: BALANCING NATIONAL AND LOCAL POLICIES

The CHP example is excellent at illustrating the economic complexities surrounding an environmentally beneficial case. The company has to factor in forecasts of heat and power demand and prices – which do usually not present a simple and nonambiguous answer. Authorities have to ponder national and local policies at the same time.

MESSAGE

Be cautious about sectoral/national/European level optimisation – it can result in big costs and little gain. The CHP case points towards this by showing the multitude of uncertainties (data and otherwise) surrounding even a local, bounded case. Optimisation of projects over a sector is usually fraught with many difficulties and hence the intended net benefits are jeopardised in the process. This problem is compounded to a frightening degree in any attempt at sectoral/national/European level optimisation. Any attempt to optimise should be undertaken only in case of obvious, beneficial combinations and even then it should be backed with positive experience from similar cases in the past.

Case 4. Energy, emissions, quality and cost

11

11.1 The specific cross-media problem

This case refers to situations where a process change is introduced with the aim of reducing emissions or achieving some other environmental advantage – and where adverse effects can be observed as changed product quality, increase in some other emissions or changes in the energy efficiency of the process. Cost impacts are also possible. The idea is to present a case where several of these effects occur simultaneously.

Possible situations are for instance:

1. Increased recycling of water in a paper machine system, with the ultimate purpose of reducing water emissions. Results may be problems with the paper quality and the runnability of the paper machine due to slime formation, internal odour problems in the paper mill, and increased amounts of solids generated in the white water treatment system. Increased temperature levels in the paper machine system may be advantageous from the energy point of view, but detrimental to the operation of a subsequent biological wastewater treatment.
2. Collection of liquor spills in a chemical pulp mill, aiming at reducing COD emissions. The collected liquor will be taken to the evaporation plant, which will increase the steam consumption in the evaporation, and thus increase the need of steam generation with a possible effect on air pollution. If the evaporation plant has a limited capacity, the total capacity of the chemical recovery plant can be negatively affected.
3. Increased use of RCF in paper furnish. In the production of newsprint, thermo-mechanical pulp (TMP) content can be reduced to some extent or even completely replaced by recycled fibre pulp (RCF). This example is analysed in detail as Case 4.

11.2 Practical example of the problem – newsprint mill

This example is a case of a newsprint mill using 40 % TMP and 60 % de-inked pulp (DIP) as furnish. The DIP is made from recycled fibre (RCF). The TMP is based on roundwood. The mill's wastewater treatment is assumed to include mechanical and biological treatment. The mill has a multi fuel boiler, for the burning of bark as well as sludge from the wastewater treatment.

The mill has two TMP-lines of which the old one needs to be replaced, while the newsprint capacity stays at 700 tons/d. The new line can either be a TMP-line or a DIP-line. In the latter case the furnish mix will change to 20 % TMP and 80 % DIP.

In case the furnish is changed, the paper quality will be affected, in one way or another. It is well known, that newsprint can be produced using a fibre mixture with high content of DIP, even up to 100 %. The composition of the furnish will, however, affect the conditions on the paper machine, as well as the paper quality. It is worth remembering that the printer clients of paper producers do not easily switch supplier, as high-speed printing machines need to be calibrated to the very specifics of paper delivered. Thus, the possibility of increasing the DIP content of the furnish will be controlled by:

- the actual paper machine design
- the customer's specifications.

This kind of raw material comparison assumes that both of the studied raw materials, roundwood and recovered paper, are sufficiently available on the markets and that also the future raw material price level can be secured to some point. In reality the price of for example recovered fibre can vary greatly and the variations, for example, on German markets have gone from negative pricing to levels several hundred percent above the average price. So, in comparison with the previous CHP case there are less price variables but greater variability.

11.3 The decision-making situation

From the company's point of view

Background: The company is medium-to-large and the investment is significant in financial terms.

Driving force: The availability and price of raw material is an important driver in this case. The price and consumption of energy is another driver for this kind of investment.

The relevant elements in the decision-making: The company has to take into account market demand and customer requirements, combined with availability and price of raw materials. In terms of machinery selection the criteria are price, operation costs and reliability.

From authorities' point of view

Background: Authorities do not regulate the company's process choices, but evaluate and supervise related changes in environmental emissions and impacts. In itself, a move to recycled fibre as a raw material is not hard to contemplate.

Relevant elements in the decision-making: Review of environmental permit conditions as a result of substantial change or a new DIP-line. Big Picture: possible increase in logistics (if the raw material has to be secured at a wider radius) combined with the possible trade-offs.

11.4 Choice of methodologies

What is the cross-media situation? Classifying the cases
(w – i – i): Severe cross-media clashes and contrasting effects. Emissions to water and energy consumption decrease, but the amount of solid waste generated increases. In addition the amount of wastewater increases while the use of other raw materials decreases.

What is our aim? Establishing environmental objectives
The environmental objective is to reduce the energy consumption and thus also indirectly the emissions to air, while maintaining or decreasing the amount of emissions to water and solid waste.

What actions should we take? Measures and sub-measures
The main measure is to design the new process line so that it follows the environmental and the economic objectives. Sub-measures include for example estimation of the emissions to different media for the two lines, cost calculations and analysis of the positive and negative effects of the project. In this example a stressor-impact analysis was made. In addition modified net present value was calculated and the impact of additional costs (in the DIP case) on production costs was evaluated.

What are the measurable environmental and economic goals?
Baseline and targets
For the baseline situation see Tables 17 and 18. In this case the target can be for example to reduce emissions to water by 10 % and energy consumption by 5 %.

What investments are needed? Related environmental investment
The main investment for both alternatives is the selected pulp line, TMP or DIP. An additional related investment required for the 20/80 alternative is a reject dewatering facility and there are also additional costs from disposing of the extra deinking sludge at a public landfill. The data for the 20/80 alternative is provided in Tables 19 and 20.

11.5 Information requirements

Information listed below is needed for the calculation of emissions and avoided cost.

Environmental data
- Raw material consumption
- Energy consumption
- Solid waste generation
- Hazardous waste generation
- Emissions to air
- Emissions to water

Economic data
- Total cost of the investment
- Operating cost
- Project life
- Nominal discount rate
- Inflation rate
- (Production cost)
- (Price of the product)

11.6 Application of the methodology

11.6.1 Information used

Data for the 40/60 Case

Environmental data

Table 17. Environmental data.

Parameter type	Parameter	Unit	Amount
Emissions to water	Waste water	m^3/d	4 425
	BOD_5	t/d	8.8
	COD	t/d	20.4
	TSS	t/d	3.3
Purchased fuels needed for power		MJ/d	3 037 040
Purchased fuels needed to steam[1]		MJ/d	2 025 040
Solid waste		t/d	120

1) The mills own biofuels are not included.

Economic data

Table 18. Economic data.

Factor type	Explanation	Unit	Amount
Total investment cost	New TMP line	€	18 500 000
Project life	Time it takes for the company to repay the investment cost	Years	15
Nominal discount rate	Alternative rate of return had the investment been made elsewhere.	%	8
Inflation rate	The source is the European average statistic performance over the last 3 years.	%	2.5

Data for the 20/80 case.

Environmental data

Table 19. Environmental data.

Parameter type	Parameter	Unit	Amount
Emissions to water	Waste water	m^3/d	5 215
	BOD_5	t/d	7.9
	COD	t/d	17.9
	TSS	t/d	2.9
Purchased fuels needed for power		MJ/d	2 312 570
Purchased fuels needed to steam[1]		MJ/d	2 454 700
Solid waste		t/d	130

1) The mill own biofuels are not included.

Economic data

Table 20. Economic data.

Factor type	Explanation	Unit	Amount
Total investment cost	New DIP line	€	14 000 000
Total investment cost	Reject Dewatering Plant	€	615 000
Operating cost (of reject dewatering plant)	Electricity, Chemicals, Maintenance, Labour	€	161 000
Project life	Time it takes for the company to repay the investment cost	Years	15
Nominal discount rate	Alternative rate of return had the investment been made elsewhere.	%	8
Inflation rate	The source is the European average statistic performance over the last 3 years.	%	2.5

11.6.2 Calculations

Environmental calculations

In this case, the environmental parameters are first divided into stressor categories and to potential impact categories (LCA framework) (Table 21). Then, the level of concern per category is analysed. This kind of method has been described in detail for example by Diamond et al. (1999).

Note: Emissions to atmosphere depend on electricity and steam generation methods and the fuels used. In this example it is assumed that the energy generation methods and the fuels are the same in both cases. Only the amount of own biofuels varies between the two cases.

The bark from TMP production is incinerated in a multi fuel boiler. The reduced TMP production means a reduced generation of bark. This is partly balanced by the increased waste and sludge amounts from the de-inking. However, to be able to use the same boiler as in case 40/60, the mill must in case 20/80 (in most cases) buy bark or wood chip residues from saw mills. For the multi fuel boiler, the net effect may include changes in the energy yield, the ash generation and the atmospheric emissions.

The TMP process also generates excess heat, which can be used on the paper machine side of the process. Again, the amount of excess heat decreases hand in hand with the decreased share of TMP produced at the site.

Table 21. Stressors and impacts.

Stressors categories	Potential impact categories	40 % / 60 %	20 % / 80 %	Percentuel changefrom 40/60 to 20/80
	POLLUTION			
Water quality stressors	Stress on aquatic species	Moderate	Moderate – Low	Decreases ap. –10 %
	DEPLETION			
Fossil fuel / external energy consumption	Primary energy source depletion	High	Moderate	Decreases ap. –5 %
Solid waste	Land or space consumption	Low	Moderate	Increases ap. +10 %
Water use	Water consumption	Low	Moderate	Increases ap. +20 %
Raw material use		Moderate	Low	Decreases ap. –15 %

Economic calculations

Case DIP-ratio 40/60 or 20/80 differs significantly from cases 1 and 2. Economically speaking the most important element is that financial returns are expected for the production line replacing the old one – be it an additional DIP or TMP line. Thus in an actual investment case the feasibility of an investment would be evaluated by calculating the NPV for it. This process is challenging due to the uncertainty surrounding numerous variables involved in these calculations. In this example it is not possible to go into such depth to use a detailed analysis and estimation of the future prices of raw materials and the end product. Also, this part of the investment is not an environment-driven investment, but a standard process investment. Hence we concentrate on the differences of the two alternatives on a quite general level.

The calculations are divided for the two alternatives. The only required investment for maintaining the 40/60 furnish mix is that required for a new TMP line. For the altered ratio of 20/80 a new DIP line is required and some additional investments and costs are also incurred related to treatment of the de-inking sludge. It should be noted that the capacity of the new production line is very low compared to modern new lines (less than 10 % of the average).

40/60 Case

The total investment for a TMP line with daily production of 60 tons/day was estimated at € 18.5 million. The required annual income ("avoided cost") is calculated like that for the previous cases i.e. by examining the point at which NPV (Net Present Value) for the investment equals zero. The project life was set at 15 years and the real discount rate at 5.5 %. However, in this case there is going to be actual income from the investment in the form of sales revenue. The required income for the investment to be economically efficient was calculated to be € 1.84 million.

The production cost estimate for the whole mill was about € 130 million annually calculated for the whole production capacity with the 40/60 furnish mix and production costs of IV/2000. At the European average price for newsprint for I/2001 the estimated income for the mill would be about € 137 million for the whole production capacity. These figures are applicable to this particular example only and must not be generalised to any other possible case.

20/80 Case

The total investment for a DIP line with daily production of 60 t/d was estimated to be € 14 million and the cost of an additional investment required (sludge dewatering system) was € 0.6 million. The total costs were thus € 14.6 million and the required annual minimum income ("avoided cost") was calculated accordingly to be € 1.46 million. The sludge dewatering can be considered an environmental investment, whereas the DIP line itself rather an ordinary process investment.

The operating costs of the facility were estimated to be € 161 000. Some of the dewatered sludge was incinerated at the mill, but the remaining excess sludge had to be deposited to a public landfill at a cost of € 362 000. The landfill cost includes transport of 20 km, which was considered a reasonable distance. When these additional costs were included the total avoided cost came up to € 1.98 million.

The production cost estimate for the whole mill was about € 128 million annually calculated for the whole production capacity with the 20/80 furnish mix and assuming production costs of IV/2000. At the European average price for newsprint for I/2001 the estimated income for the mill would be about € 137 million for the whole production capacity.

Comments

There are a few important facts to bear in mind when looking at the financial side:

- The quality of the end product changes when the furnish mix is altered but this is not reflected in the market price of the end product (newsprint).
- The prices of raw materials (round wood and recycled fibre) are volatile and greatly influence the economic position of the investments and the mill.
- The estimates provided apply only to this particular case and only to the provided time period. The costs and necessary investments are highly mill-specific and vary over time.

There is a small difference in production costs in favour of the 20/80 alternative: the production costs per ton of product are 1.7 % less than in the 40/60 case. It has to be noted that the raw material price for RCF had just risen in the last quarter of 2000 and this was reflected in prices only several weeks later in the first quarter of 2001. Thus we have selected these figures for the basis of comparison. The raw material price for RCF in IV/2000 was above its long-term average price (trend price).

However, it should be kept in mind that the availability of the raw material is a very important element in deciding between these alternatives. Where wood is readily available at a reasonable price the producer would lean towards TMP and the same reasoning applies to RCF. It is also a question of demand and preferences of the major customers.

Value calculations

The value added in this case is changed due to the raw material change. Here, the furnish is changed so that less TMP and more DIP are used. Depending on the raw material market prices this shift can bring either positive, negative or no effects at all. If the raw material price is higher for DIP than for TMP then the investment will, of course, be less profitable. In case DIP is less expensive than TMP the results will be the opposite.

In the second step the clients determine the value of the action. How much the clients are willing to pay for the newspaper and what quality they demand are the most important factors affecting the value in this step. The newspaper price, which is linked to demand, determines whether the product is valuable or not.

In the third phase the value of the paper is reduced by it becoming waste. The product has no longer any value for customers, traders nor the mill. Collectors must step in to start the transformation towards a product. This productisation can occur by conversion to energy (sales to incineration plants) or to paper (sales to mills as recovered paper). In the former case, if incineration occurs without energy recovery, no value is created, a waste management problem is solved at a cost. In the paper mill value is added further when the recovered fibre is reused as raw material to paper or packaging again. Formation of value is shown in Figure 34.

Value for society and environment

The environment and society are affected differently in the alternative cases. In this case when no significant differences in the emissions from alternative raw material furnishes are present, it is fair to say that the most important parameter affecting the value is the location where the process in planned to be built. Different countries have different types of industrial eco-systems (which have an impact on raw material availability) and social networks (affecting the logistics and employment aspects). Therefore, a socio-economic-environmental evaluation would need to go deeper in detail than is possible here.

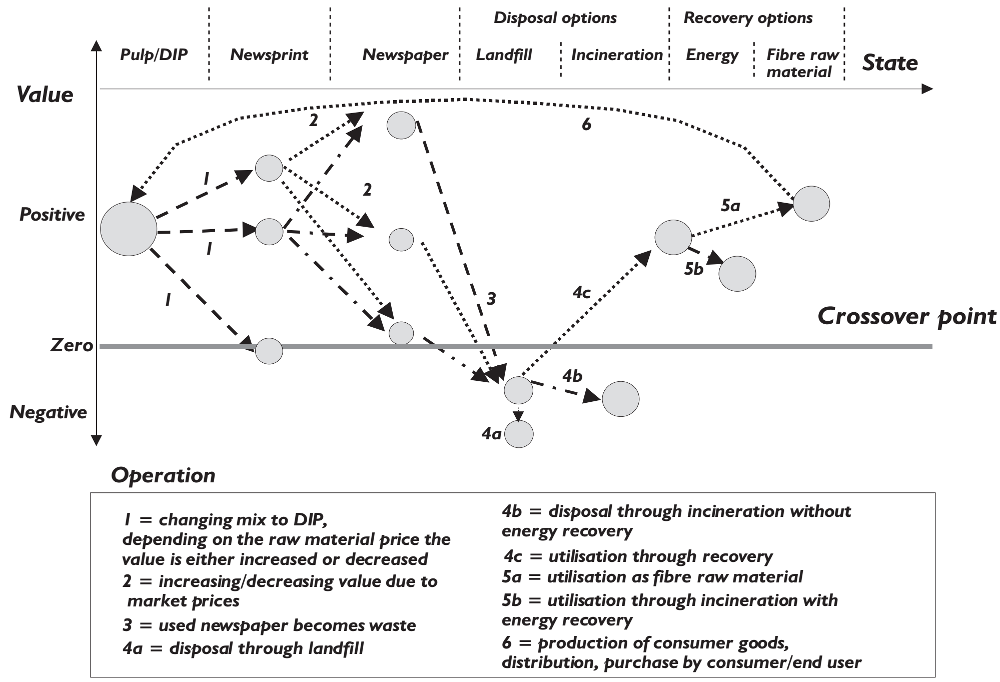


Figure 34. Value diagram for Case 4.

11.7 Conclusions

As was said in the introduction to this case, this comparison is based on the assumption that both of the studied raw materials, roundwood and recovered paper, are well available on the markets and that also the future raw material price level can be secured or estimated to some degree. There are pros and cons in both of the alternatives and the case is even less black and white than the earlier cases.

Figure 35 below summarises the initial objectives and action plan for the case example.

	Cross-Media Clashes	Type	Environmental objectives	Measure	Sub-Measure	Baseline 200x	Target 20YZ	Related Enviro-Investment
SEVERE CLASH / POSITIVE	emissions to water (i) energy consumption (i) solid waste (w)	iiw	To reduce the energy consumption and thus also indirectly the emissions to air while maintaining or decreasing the amount emissions to water and solid waste.	To choose the new process line so that it follows the environmental and the economic objectives.	Estimation of the emissions to different media of the two lines, cost calculations and analysis of the positive and negative effects of the project.	The current emission level, that is the emissions of the 40/60 case.	For example to reduce emissions to water by 10 % and energy consumption by 5 %.	The main investment is the selected pulp line, TMP or DIP. Depending on the choice, some other investments for example in landfill might be needed.

Figure 35. Cross-media action table.

Advantages and disadvantages:

In case the mill chooses to invest in a new DIP line instead of TMP (the 20/80 alternative)

+ BOD_5 decreases approximately 10 %, COD –12 % and TSS –12 %.
+ The amount of external fuels needed for all electricity (both own production and purchased) used decreases approximately 20 %
+ Production costs may be slightly lower (at cost structure IV/2000)
– Wastewater amount increases 20 %
– The amount of purchased fuels needed for steam production increases 20 %.
– Solid waste amount increases almost 10 %
– Costs from treating additional de-inking sludge and landfilling waste

When the furnish mix is changed, the paper quality will be affected, in one way or another. In this kind of investment decisions the effect of the quality change on the customers' expectations must be carefully evaluated.

Figure 36 shows a rug plot matrix consisting of selected main parameters of the case. For detailed explanations on these matrixes, please see Chapter 8.7 and Figure 24. As can be seen in Figure 36, in case the mill chooses to invest in a new DIP line instead of TMP (the 20/80 alternative), a number of environmental effects will result.

Electric power consumption of the pulping is reduced (DIP preparation requires less power than TMP pulping) but steam consumption increases. The sum of these changes shows that the overall fuel consumption decreases. The DIP preparation will give a solid residue, with two main components: the rejects and the de-inking sludge. The rejects are normally landfilled. The de-inking sludge is dewatered, and then normally either landfilled or incinerated in a multi fuel boiler, so there will be an additional amount of solid waste to landfilling. The fossil fuels are compared to the amount of solid waste in the second box on the left in Figure 36. A indicates the 40/60 case and B the 20/80 case. Because, in case the mill chooses to invest in a DIP-line, the amount of fossil fuel decreases while solid waste generation increases, the box is light grey in colour.

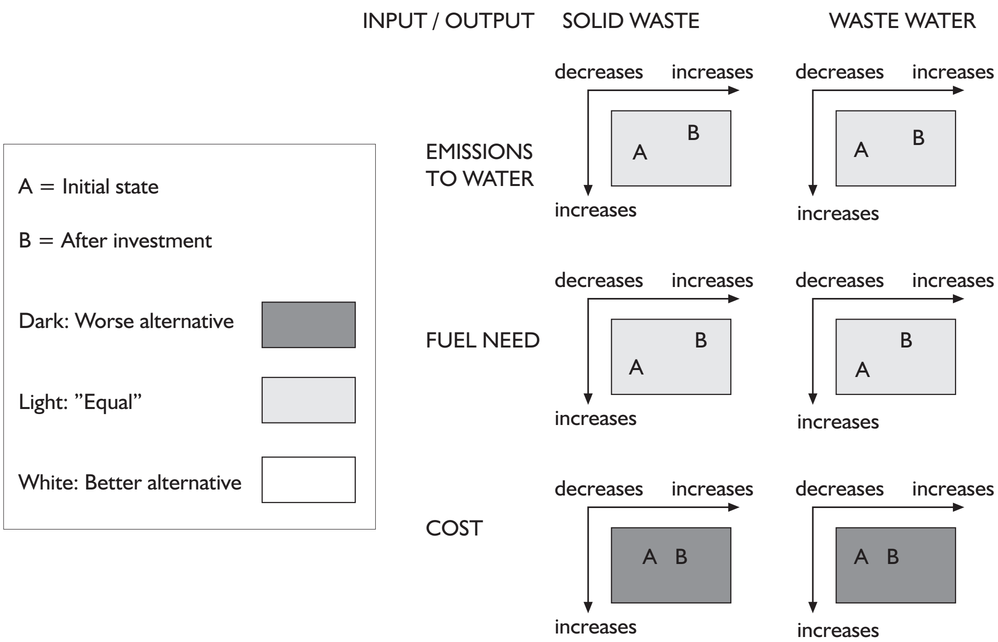


Figure 36. The rug plot matrix for Case 4.

The emissions to water, in terms of BOD, COD and TSS, are changed. The emissions from the DIP-line are lower than emissions from the TMP-line. However, the wastewater amount is higher for the 20/80 case. This is why also the emissions to water vs. wastewater box, the first box on the right in Figure 36, is light grey.

The other boxes follow the same logic. The relative price of the raw materials has a significant impact on the production costs. In this case the difference was less than 2 % and thus the production cost factor was interpreted to stay constant in the rug plot matrix. The two boxes below turned dark grey because the amount solid waste and wastewater increased resulting in negative total effect.

As also the rug plot matrix indicates – the choice is in the end up to the producer facing a unique production environment. The availability and cost of the raw materials together with the preferences of the customers carry significance. Neither is there environmentally any clearly better alternative. Both alternatives have their advantages and the disadvantages of neither can be considered worse e.g. in terms of emissions.

SPECIAL LESSON FROM CASE 4:
BALANCING QUALITY, ECONOMY AND ENVIRONMENT

In this case, we are dealing with an investment with complex environmental clashes between the alternatives. The cost impacts depend on the simultaneous development of several price variables. In this balancing act, there should not be an oversimplification in the methodology. These cases are all individuals, and costly. Moreover, generically, if the quality of the product is worsened too much, there is no value, only waste.

MESSAGE

Local optimisation of only some parameters may lead to changed product quality and no or little gain for the environment.

12

Conclusions

As a general conclusion it can be highlighted that the selection of methods is very case-specific. Different methods have to be used to tackle different types of problems and issues. The case specific goals and circumstances have to be considered. It should also be acknowledged that methods have individual weaknesses that can be counteracted by choosing a selection of methods that complement each other.

12.1 The subsidiarity principle applies

The European Community's subsidiarity principle, which can be stated as "make the decisions at the lowest appropriate level", certainly applies here. There are local cross-media clashes, and cross-media clashes on European level, brought on by differing national policies. Yet, for a local issue, while it is essential to remember the Big Picture, it has to be permitted to think about the local conditions. Otherwise, a massive centralisation will produce a severe backlash – and given the current state of enviro-economic assessments and data availability, it would be foolhardy to risk the European environment on the basis of some high-level, abstracted calculations.

12.2 Environmental problems move across dimensions

Environmental problems move across dimensions and take all sorts of shapes, like a virus mutating, but the knowledge to solve them can be replicated. We propose that the idea of a European information base on actual cases of solved cross-media problems be evaluated. In order to enhance exchange of information on cross-media and economic aspects on European level it would be useful to highlight appropriate cases in sectoral BAT Reference Documents.

12.3 Evaluation of methods

Economic methods

Annualised capital charges/avoided cost approach. This type of a method is well suited for environmental investments. The avoided cost approach was applied to several case studies in this report. It is important to keep in mind that the meaning of the avoided cost is to show a limit value for an economical approval of an investment i.e. the smaller the value, the lower the threshold to invest. However, this method only gives the magnitude of an investment as a result. Still, it can be used for calculating for instance indicative cost-effectiveness values.

NPV. NPV is a standard tool for investment appraisal and it can be applied when the expected returns of an investment are known. Modifications of the method may be applied to environmental investments. One problem associated with the method is discounting of the future. For instance the concept of environmental risk is such that the benefits of action today that materialise in the future should not be discounted.

Option value. The option value concept is useful with environmental investments, but also with any investments that have an impact on the environment. It supplements the NPV but also has similar disadvantages. Option value calculations also require that there is some financial return from the investment.

Cost-effectiveness evaluation. This method combines economic data with environmental data and enables effectiveness comparisons between two investment alternatives. A commonly used evaluation, which has also been used in e.g. Chapter 8 (case 1), is one where the result is given in the form currency units/unit of emission abated. The method can also be used also in cross-media evaluations provided that the costs have been properly allocated to the emission sources. If the emission sources, investments and emissions are properly identified, it can be used to show what money can buy. There is no attempt to convert emissions into money but just to show in a practical way what the money can buy.

Environmental methods

Environmental impact assessment, particularly in the context of environmental permitting, has usually the following steps:

1. Identification of the significant emissions, risks, raw material use, energy efficiency and other significant environmental or health aspects, such as noise, odours, vibration, species and habitat protection, hygienic conditions and aesthetic values. The requirements of the common (EU, national, regional) emission norms and targets as well as bans and restrictions on chemicals should be taken into account at the early stage of evaluation.
2. Assessment of the fate and exposure of significant pollutants with methods of appropriate complexity, comprehensiveness and sophistication. This is not necessary for pollutants with insignificant effects on the local environment.
3. The significant local impacts should be evaluated against the local environmental and health quality standards and objectives where they exist. In addition to disaggregated impact assessment an aggregated approach following e.g. the LCA framework may provide useful additional information for decision making.
4. Identification and analysis (environmental and economic) of cross-media clashes. Methods are chosen case specifically.

General guidelines for choosing methods (economic or environmental)

- Information management and availability of precise data records has an impact on methods chosen. If data is readily available and economic returns can be quantified e.g. NPV/Option value can be used. If the data is given at a general level e.g. Annualised Capital Charges method may be applied.
- It matters, whether the company makes a single investment or multiple investments at a time. In the latter case acitivity based costing (ABC) can be applied to both costs and emissions provided that data is available.
- Size of the investment and complexity of the problem determine the amount and nature of methods applied. In a large case with complex impacts it is often useful to use several methods that complement each other and perhaps even partly overlap each other.

12.4 Collected lessons and messages

Special lesson from cases

Use of pragmatic, constructive realism in evaluating a trade-off. Don't follow any method slavishly. Several methods coupled with expert judgement provide a fair starting point. If a result is desirable, and the trade-off is worth it for reasons of common sense and case specifics, go for it.

The value of environmental innovation. For the company, its embarkment on a path of environmental innovation can be pondered also e.g. in environmental image. However, the real focus is on the authorities: should there be special allowances for environmental innovation activities, especially ones with wide potential positive ramifications?

Balancing community, national and local policies. The CHP example is excellent at illustrating the economic complexities surrounding an environmentally beneficial case. The company has to factor in forecasts of heat and power demand and prices – which do usually not present a simple and nonambiguous answer. Authorities have to ponder national and local policies at the same time.

Balancing quality, economy and environment. Sometimes we are dealing with an investment with complex environmental clashes between the alternatives. The cost impacts depend on the simultaneous development of several price variables. In this balancing act, there should not be an oversimplification in the methodology. These cases are all individuals, and costly. Moreover, if the quality of the end product is worsened too much, there is not value, only waste.

Message

- IPPC is not easy, even for one piece of equipment.
- Optimisation of one parameter may just be a transfer from one pocket to another.
- Be cautious about sectoral/national/European level optimisation – it can result in big cost and no gain. The CHP case points towards this by showing the multitude of uncertainties (data and otherwise) surrounding even a local, bounded case. This problem is compounded to a frightening degree in any attempt at sectoral/national/European level optimisation.
- Local optimisation of only some parameters may lead to changed product quality and no or little gain for the environment.

13 Summary

Introduction to the topic

The objective of this study is to give support to the Finnish contribution in the preparation of the EU reference document on economic and cross-media aspects (ECM REF). Typical examples of cross-media issues include waste generation and energy consumption against emission abatement or air emission reduction against increase in wastewater emission and energy consumption. The core contents, the structure of the report and the case chosen from industry are described briefly in this summary. The methodology and application of the methods presented are described in detail in the report.

One of the main purposes of the IPPC Directive is to achieve a high level of environmental protection as a whole against the pressures arising from the activity of an industrial installation. The integrated and holistic viewpoint of the Directive covers all media – air, water and soil, energy efficiency and use of raw materials. Economic viability, cost-effectiveness and consideration of costs and benefits are part of the notion of Best Available Techniques (BAT) forming the basis of technical measures required. The scope of the directive does not extend to the manufacture and transportation of raw materials and transportation, use or disposal of products. Hence a full life cycle assessment is not directly applicable to the cross-media assessment in accordance with the IPPC Directive. IPPC Directive is also not applied to global impacts, such as global warming.

The cross-media assessment is complicated by the intrinsic complexity of raw materials, processes, mass flows and structure of facilities. The number and complexity of cross-media aspects varies significantly between different sectors and installations. If significant cross-media conflicts appear, a preferably quantitative analysis on the local level is needed before a balanced decision can be made.

The goal of this study is to:

- identify problems and trade-off issues related to the integrated management of emissions and other impact factors,
- introduce methods to deal with cross-media issues,
- illustrate possibilities for the integrated assessment of environmental harms and benefits in local permitting procedure; and
- depict data on costs and costing methodology of environmental protection measures for industrial activities.

Relevant methods and study perspectives

Significance of angle of view

Public authorities and politicians determine goals for environmental policy. Companies aim to carry out them in practice. Hence it is useful make a distinction between the private sector (e.g. company level) and the public sector (e.g. nation state or EU level) economic point of view. There is always a risk that a company may not find an investment worthy to make although it would be socially desirable. On the other hand, a company may make an investment that is not desirable from a national economic or societal point of view even though the private company would consider it profitable.

The obligation to have a permit for operating an industrial installation, which emits environmentally harmful substances, is the result of preceding steps in environmental policy making. These preceding steps have not been taken in isolation; instead the criteria for granting a permit are usually the result of negotiations between various stakeholders. The cross-media benchmarks that are based on BAT do not only take environmental limits into account but also economic feasibility. The balance between economic feasibility and environmental requirements can be achieved in many ways. Apart from varying emission limits as such, aspects such as subsidy schemes, the length of the transition period toward compliance, and R&D programmes for better and/or cheaper abatement technologies can all be part of the solution.

The nature of environmental investments

On a general level, it can be stated that environmental regulation obliges industries to lower their environmental load. This in turn implies that most of them will have to invest in new technology. Some costing frameworks, methods and concepts applicable to assessment of environmental investments are introduced. Environmental investment analysis is closely related to environmental accounting. Traditionally an investment is expected to produce economic returns to the company but a pure environmental investment lacks such requirements. On the national or EU level the adoption and development of environmental technology depends on demand, R&D efforts and relative prices as well as on policy incentives.

In real life it is actually often hard to make a clear distinction between an economic and an environmental investment. Investments that fall between these categories are common, e.g., an environmental investment which at the same time saves energy hence also money. This ambiguity poses a challenge to the determination and accounting of investment costs. The environmental investments are starting to involve sufficiently high costs that they should no longer be allocated into general overhead as has been done previously.

Costing methods and concepts

Only the costing of internal environmental measures of a company is considered. From a societal point of view the expenses incurred from these investments may be called "private costs". Life cycle costing and valuation of environmental harms and benefits involve costs to external parties, and are thus beyond the scope of this chapter. Environmental costing is increasingly important for companies. At the same time when environmental measures have shifted emphasis from end-of-pipe-type technologies to process-integrated measures the task of allocating the costs has become increasingly difficult. Allocation of costs or distinguishing and separating the costs of an environmental investment from other investment is also certainly among the greatest challenges to environmental costing.

The subchapter is divided into two parts according to the role individual methods and frameworks play in investment sequence:

1. Investment Appraisal – Total Cost Assessment (TCA) complemented with Net Present Value (NPV), Annualised Capital Charges and Option value are introduced. Cost-Effectiveness Analysis is also briefly described.
2. Cost allocation – The accounting method Activity Based Costing (ABC) is described.

At the end of each section there is a very brief summary of examples on how the individual method can be used by a company.

Evaluation of environmental harms and benefits

In the IPPC context, the environmental harms caused by industrial operations are related to the emissions into water and air, waste streams, use of energy and raw materials. Similarly environmental benefits appear as a result of decrease in the inputs and emissions. A common way of assessing the harms and benefits is to distinguish the impacts on ecosystems, human health, amenities and other uses. On the other hand the impacts can be classified on the basis of their geographical scale into local, regional and global categories.

The following issues are usually determined step-wise in the evaluation of environmental impacts caused by an industrial installation:

- quality and quantity of emissions of harmful substances, waste, noise and thermal load including the temporal variations and disturbances;
- efficiency of energy use and environmental aspects of raw materials;
- transportation, degradation, accumulation and transformation of emitted harmful substances and the exposure of organisms, humans and structures;
- impacts of emissions, waste streams, noise and thermal load on organisms, populations and habitats as well as on human health and amenities; and
- significance of impacts from the point of view of natural ecosystems, humans and society.

In the report also different weighing methods for environmental impacts are discussed. As a whole it can be concluded that a great deal of uncertainty and subjectivity is related to all weighting methods. Hence one has to be extremely cautious of the many-faceted implications, if weighting is applied to the evaluation of the environmental harms and benefits.

Integration of economic and environmental aspects

Integrated analysis has to take into consideration the boundaries of economic sense and targeted level of environmental protection. Conflicts between these drivers do occur but at other instances environmental protection measures may have an effect of same direction on both economics and the environment.

Value is a key concept in our analysis. Value can be added or destroyed in the process of attempting to solve a problem. At a certain point there is a cross over at which time for example the value of a product becomes negative, as it is classified as waste. This could be called "value crossover" of cross-media impacts. Also the investments' impact on social and environmental value is described. The illustrative Value Diagram is shown in Figure 37.

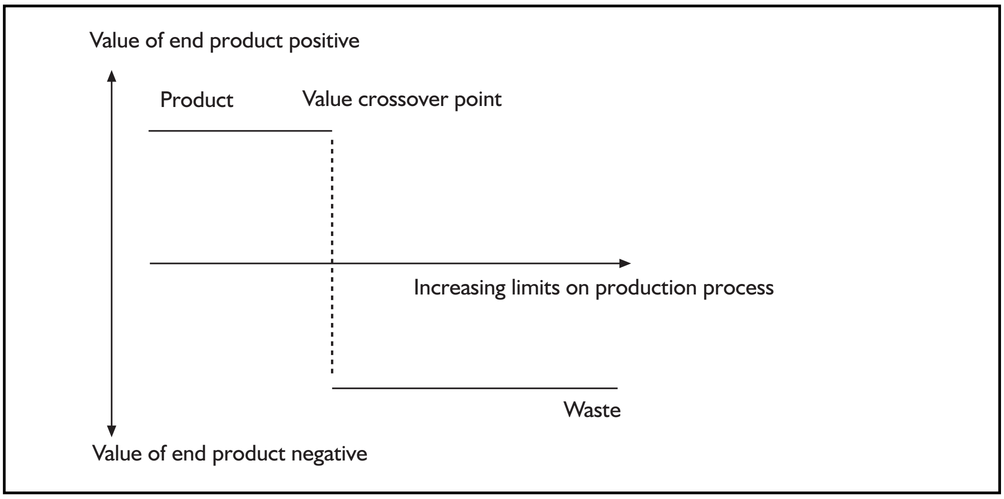


Figure 37. The value diagram.

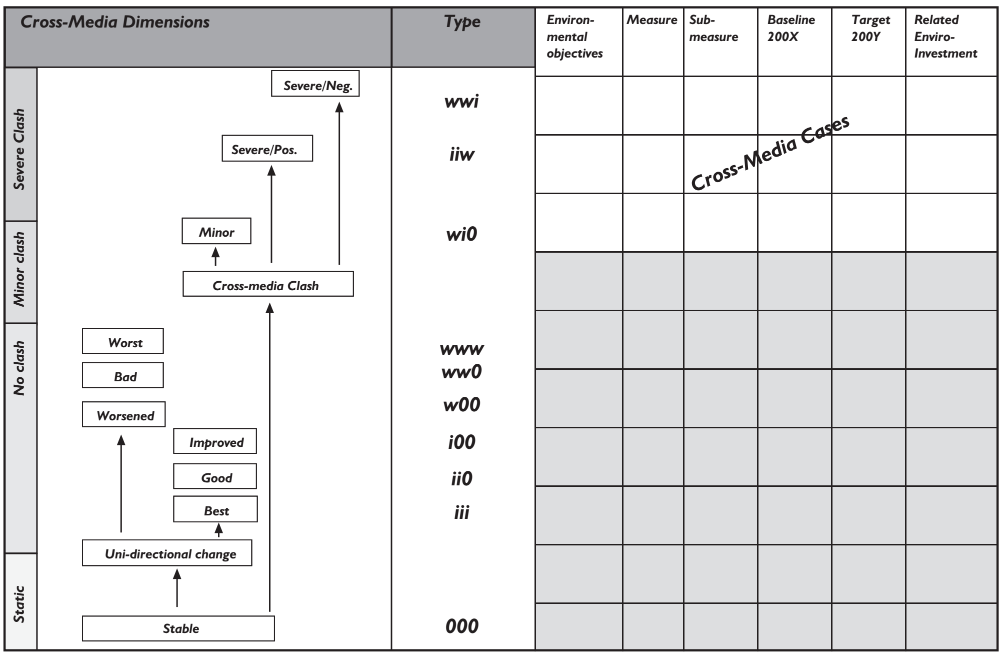
Plot for method combinations

In a framework for cross-media assessment, a scientific basis must be linked to practical solutions. Encountering and solving cases in practice promotes deeper understanding of cross-media phenomena. In order to establish the integrated assessment of practical cases three principles have been developed. Our guiding principle is what we call "The Lens Principle" and our practical tools include the "Cross-media Action Table" and the "Perspective List". The basic idea of the Lens Principle is: the more complex and serious the cross-media problem, the wider the angle of different perspectives needed, that is: more serious cross-media clashes require more analyses. In a simple case, a smaller selection of analyses is sufficient; in a complex incident, many viewpoints are needed. It also depends on what "lens" we are using when looking at the problem. The "Perspective List" is linked to the classification part of the Action Table. The list is a set of recommended combinations of analyses to perform for certain basic types of cases. Insofar as it is possible, the different perspectives are given names. The Cross-media Action Table is given attention through the following figures (Figure 38 and Figure 39) and explanations.

The "Cross-media action table"

The Cross-media Action Table contains answers to the following questions:

- **What is the cross-media situation?**
  A flowchart of cross-media classification and an encoding of cross-media effects
- **What is our aim?**
  Environmental objectives (established for a specific case)
- **What actions should we take?**
  Measures and sub-measures to be taken (related to environmental objectives). Actions include analyses to undertake from the Perspective List.
- **What are the measurable environmental and economic goals?**



Class Type Codes: w=worsening, i=improving, 0=no change to the original situation

Figure 38. Cross-media action table.

A baseline and a target (on a timeline), with measurable environmental and economic objectives

- **What investments are needed?**
  Related environmental and other investments

The Cross-media Action Table has been applied to a case study in Figure 39.

Introduction to case studies

The problem of many dimensions
The amount of cross-media problems to analyse is fairly large, though not infinite. In this study, we first

- Choose the dimensions to be examined, and then
- Choose the example problems.

The chosen cases were the following:

1. A case illustrating trade-off between air and solid waste – and cost.
   • This is a pure environmental investment.
2. A case illustrating trade-off between water and solid waste – and cost.
   • This case demonstrates the adaptation of new technology.
3. A case illustrating trade-off between energy and air/water/solid waste – and cost.
   • This is a case where location and infrastructure are important.
4. A case illustrating trade-off between energy, emissions and product/service quality – and cost.
   • Raw material availability is a key issue in this case.

Case 1: Air and solid waste – and cost

To demonstrate the cross-media problem of air / solid waste and cost, a case, in which a company having a multi fuel boiler invests in a wet scrubber, is analysed. This is a pure environmental investment.

The decision-making situation
The decision-making situation is described both from the point of view of the company and the environmental authority. In this case the company is of medium size

Cross-Media Clashes		Type	Environmental objectives	Measure	Sub-Measure	Baseline 200x	Target 20YZ	Related Enviro-Investment
SEVERE CLASH / NEGATIVE	acidic emissions (i) emissions to water (w) solid waste (w)	iww	To reduce the acidic emissions to air while maintaining or decreasing the amount of solid waste and emissions to water.	To build a scrubber.	Estimation of the emissions to different media with and without the scrubber, cost calculations and analysis of positive and negative effects.	SO_2 610 mg/m^3 HCl 50 mg/m^3 Particles 30 mg/m^3	Get acid emissions clearly below national target levels.	The scrubber and a landfill for the scrubber waste.

Figure 39. A practical example of cross-media action table: Case 1.

and the investment is small/medium size for it. The primary driving force for making the investment is the existing legislation. Other relevant elements for the decision are the price and accountability of the machinery, other costs and how the company is able to deal with the arising solid waste problem.

From the authorities point of view the company may have to apply for a change in its landfilling permits. The policy of the authorities as regards reducing of air pollution vs. the waste management policy is the most relevant element in the decision-making.

Advantages and Disadvantages

+ SO_2 emissions decrease nearly by 90 %
+ HCl emissions decrease by 80 %
– Generation of solid waste increases by 5 m^3/d
– Increased energy and raw material consumption
– Fairly costly investment and expensive to maintain

Case 2: Water and solid waste – and cost

This problem is a general one, common to several processes for treating wastewaters. In these processes the contaminants in the water are in some way transferred into solid particles, which are collected into sludge, finally ending up as a solid waste.

As an example we choose a case from CTMP (Chemithermomechanical Pulp) production, where a water system very near a closed cycle exists. The wastewater, with a low flow due to a high rate of recycling, contains dissolved organic matter, dissolved from wood in the pulping process, and dissolved inorganic matter, residues of the pulping chemicals. There are two potential methods to treat the wastewater. The traditional way is to use biological water treatment. Another, less applied method is evaporation of the wastewater, so called Zero Effluent process

In this case a mill producing 400 ADt/d CTMP plans to invest either to a biological wastewater treatment plant or to a Zero Effluent system. The effects of the two investment alternatives are compared.

The decision-making situation

The decision-making situation is described both from the point of view of the company and the environmental authority. In this case the company is of large size, the investment is in new technology and financially significant. The primary driving force for making the investment is to minimise the amount of wastewater produced. Other relevant elements in the decision are the price of the machinery and references of the supplier. There is a conscious risk to be taken, because the technology is new. Land use issues are also important.

The authorities will likely monitor the reliability of the equipment suppliers, gather experience, hope for results and have the possibility to encourage environmental innovations.

Advantages and disadvantages

There is a definite clash in this case. It is a matter of preference, whether water emissions or solid waste is a point to focus on. Referring to the avoided cost calculations the economically preferred alternative would be the biological treatment. However, the value of environmental innovation, especially in an area of high significance, should not be discounted.

Case 3: Energy and air/water/solid waste – and cost

To demonstrate the cross-media problem of energy, emissions and cost, a case in which a CHP (combined heat and power) plant is compared to a traditional condensing power plant is presented. If costs of avoiding pollutant emissions are calculated, large-scale cogeneration is one of the cheapest methods of pollution abatement, in addition to being a method of energy conservation.

When energy is produced from fossil fuels, the plants with highest energy efficiency are also the ones with least emissions. This means that there is no cross-media problem between energy efficiency and emissions. However, if costs are added to the equation, the situation gets more complicated. CHP plants convert 40–70 % of the energy input into heat and 20–45 % into electricity depending on the CHP system. For cogeneration to compete successfully in the marketplace, a high price of electricity and a big enough local heat demand are required.

Our case study compares the alternatives of the current CHP production and that of separate production for a regional energy system of a Finnish city. In the separate production alternative heat is produced in a plant that uses a fuel mix identical to the current plant and electricity is produced in a condensing power plant that uses coal as fuel.

The decision-making situation

The decision-making situation is described both from the point of view of the company and the environmental authority. In this case the company is of large size, the investment is strategically and financially significant. The primary driving force is the current and forecasted price of electricity. The decision-making process is quite complex. The demand for heat and electricity has to be estimated. The fuel prices and their estimated future developments are taken into account. The company also has to take into account that once a CHP plant has been made it cannot easily be converted for other kinds of electricity production (the system is fairly rigid once it is in place).

As a background for the authorities' part can be said that this issue receives highly varied and perhaps even colourful treatment across Europe. Measures on encouragement of investments in CHP are prepared in Brussels, while authorities around the continent grapple with national and local level issues. Other relevant elements for authorities' decision-making, to name but a few, are: what are the goals for electricity production? Is there a strategy for fuel mixes? What is the relationship between national and local authorities?

Advantages and disadvantages

+ Higher energy efficiency
+ Considerably lower emissions
– Requirement of demand for both electricity and heat
– Unprofitability at certain fuel and electricity price levels

CHP is a better alternative in what comes to emissions to air and fuel consumption, whereas the cost situation is completely time and case dependant.

Case 4: Energy, emissions and product/service quality

This case refers to situations where a process change is introduced with the aim of reducing emissions or achieving some other environmental advantage – and where adverse effects can be observed as changed product quality, increase in some other emissions or changes in the energy efficiency of the process. Cost impacts are also possible. The idea is to present a case where several of these effects occur simultaneously.

This example is a case of a newsprint mill using 40 % TMP and 60 % de-inked pulp (DIP) as furnish. The DIP is made from recycled fibre (RCF). The TMP is based on roundwood. The mill's wastewater treatment is assumed to include mechanical/biological treatment. The mill has a multi fuel boiler, for the burning of bark as well as sludge from the wastewater treatment. The mill has two TMP-lines of which the old one needs to be replaced, while the newsprint capacity stays at 700 tons/d. The new line can either be a TMP-line or a DIP-line.

The decision-making situation

The decision-making situation is described both from the point of view of the company and the environmental authority. In this case the company is of medium-to-large size and the investment is financially significant. The primary driving force is the availability and price of raw material. The price and consumption of energy is another driver for this kind of investment. The company has to take into account market demand and customer requirements, combined with availability and price of raw materials. In terms of machinery selection the criteria are price, operation costs and reliability.

The authorities do not control the choice between process alternatives, but a review of environmental permit conditions is necessary, when there is a substantial change or a new DIP-line is built. The move to recycled fibre as a raw material is not hard to contemplate. In the overall picture the authorities have to consider a possible increase in logistics (if the raw material has to be secured at a wider radius) combined with the trade-offs.

Advantages and disadvantages

In case the mill chooses to invest in a new DIP line instead of TMP (the 20/80 alternative)

- \+ BOD_5 decreases approximately by 10 %, COD by 12 % and TSS by 12 %.
- \+ The amount of external fuels needed for all electricity (both own production and purchased) used decreases by approximately 20 %
- \+ Production costs may be slightly lower (at cost structure IV/2000)
- – Wastewater amount increases 20 %
- – The amount of purchased fuels needed for steam production increases 20 %.
- – Solid waste amount increases almost 10 %
- – Costs from treating additional de-inking sludge and landfilling waste

When the furnish mix is changed, the paper quality will be affected, in one way or another. In this kind of investment decisions the effect of the quality change on the customers' expectations must be carefully evaluated.

Conclusions of the study

Evaluation of the methods

The companies' activities often cause environmental impacts that are multi-dimensional. The selection of methods for analysis has to be done based on the case and considering possible uncertainties. The companies and authorities have to base their decisions on available information. There are often also stakeholders' interests related to the environmental investments or innovation activities that have to be examined and taken into account.

The questions related to selection of methods can be summarised as follows:

- Is there a need to use these types of methodologies? **Yes** – without them, any relevant evaluation will be sorely lacking in substance.

- Is there one method, which should be chosen as the standard? **Definitely not.** The methods highlight different aspects of the issues and, used alone and without carefully considering their weaknesses, run the risk of a seriously skewed picture.
- If we can only use one method, which do we choose? **That depends entirely on the situation.** The question asked, the goal of the study, the circumstances all dictate the choice – which may not be easy.
- Even when using a carefully selected method (or combination of methods), what is essential? **Being aware of, discussing and considering the particular weaknesses of the methods chosen and the consequences.**

On the nature of cross-media effects

Cross-media deliberation can be regarded as a pursuit of the best balance between emissions into air, water and soil as well as high energy-efficiency and prudent use of raw materials achieving a high level of environmental protection as a whole. In the integrated assessment of different types of environmental and health impacts, e.g., ozone depletion, acidification, tropospheric ozone formation, eutrophication, ecotoxicity, biodiversity, human health and nuisances trade-offs need to be determined. Trade-off judgements involve transparent arguments, in favour of a certain balance between different environmental and health aspects. It has to be recognised that cross-media and trade-off assessments inevitably involve value judgements. One of the features of value judgements is that they tend to change over time. Hence there are no single calculation rules and methodology available that could produce the objective and correct solution to the cross-media problems.

Lessons Learnt from the Case Studies

- In evaluating a trade-off – don't follow any method slavishly. If a result is desirable, and the trade-off is worth it for reasons of pragmatic, constructive realism and case specifics, go for it.
- For the company, its embarkment on a path of environmental innovation can be pondered also e.g. in environmental image. However, the real focus is on the authorities: should there be special allowances for environmental innovation activities, especially ones with wide potential positive ramifications?
- Balancing of national and local policies is challenging. The CHP example is excellent at illustrating the economic complexities surrounding an environmentally beneficial case. The company has to factor in forecasts of heat and power demand and prices – which do usually not present a simple and unambiguous answer.
- Sometimes we are dealing with an investment with complex environmental clashes between the alternatives. The cost impacts depend on the simultaneous development of several price variables. In this balancing act, there should not be an oversimplification in the methodology. These cases are all individuals, and costly. Moreover, if the quality of the end product is worsened too much, there is not value, only waste.

The subsidiarity principle applies

The European Commission subsidiarity principle, which can be stated as "make the decisions at the appropriate level", certainly applies here. There are local cross-media clashes, and cross-media clashes on European level, brought on by differing national policies. Yet, for a local issue, while it is essential to remember the Big Picture, it has to be permitted to think about the local conditions. Otherwise, a massive centralisation will produce a severe backlash – and given the current state of enviro-economic assessments and data availability, it would be foolhardy to risk the European environment on the basis of some high-level, abstracted calculations.

Environmental problems move across dimensions and take all sorts of shapes, like a virus mutating, but the knowledge to solve them can be replicated. We propose that the idea of a European information base on actual cases of solved cross-media problems be evaluated. In order to enhance exchange of information on cross-media and economic aspects on European level it would be useful to highlight appropriate cases in sectoral BAT Reference Documents.

14 Tiivistelmä

Johdanto

Tutkimuksen tarkoituksena oli tukea Suomen osallistumista taloutta ja ympäristöllisiä ristikkäisvaikutuksia koskevan EU:n vertailuasiakirjan (ECM REF) valmisteluun. Tyypillinen esimerkki ristikkäisvaikutuksesta on tilanne, jossa päästöjen vähentämisen seurauksena syntyy enemmän kiinteää jätettä ja kuluu enemmän energiaa tai toisaalta tilanne, jossa päästöjä ilmaan onnistutaan vähentämään jäteveden päästöjen ja energian kulutuksen kustannuksella. Tiivistelmässä kuvaillaan tutkimusraportin keskeistä sisältöä ja rakennetta sekä annetaan lyhyt kuvaus teollisuudesta valituista esimerkeistä. Varsinaisiin menetelmiin sekä niiden soveltamiseen tapaustutkimuksissa voi perehtyä tarkemmin englanninkielisen tutkimusraportin avulla.

Eräs IPPC-direktiivin päätavoitteista on saavuttaa kokonaisuudessaan korkea ympäristönsuojelun taso ottaen huomioon teollisen toiminnan aiheuttamat paineet. Direktiivin yhtenäisessä ja kokonaisvaltaisessa lähestymistavassa otetaan huomioon kaikki ympäristön osat – ilma, vesi ja maaperä, sekä lisäksi energiatehokkuus ja raaka-aineiden käyttö. Ympäristöinvestoinnin aiheuttaman taloudellisen rasituksen kohtuullisuus, kustannustehokkuus sekä kustannusten ja hyötyjen arvointi ovat osa BAT-käsitettä, joka muodostaa pohjan vaadittaville teknisille toimenpiteille. Raaka-aineiden tuotanto tai kuljetukset, sekä tuotteiden kuljetukset, käyttö ja hävitys eivät kuitenkaan ole direktiivin piirissä. Direktiivi ei myöskään koske ilmastonmuutoksen kaltaisia globaaleja vaikutuksia, eikä vaadi ympäristövaikutuksia arvioitavaksi täydellisen elinkaarianalyysin edellyttämällä tavalla.

Raaka-aineiden, tuotantoprosessien, massavirtojen ja laitosten rakenteen monimutkaisuus on niihin liittyvien ristikkäisvaikutusten arviointia vaikeuttava tekijä. Ristikkäisvaikutusten määrä ja monimutkaisuus vaihtelee suuresti niin eri toimialojen kuin yksittäisten laitostenkin välillä. Tämän takia niiden tarkasteluun täytyy soveltaa monenlaisia menetelmiä.

Tutkimuksen tavoitteena on:

- tunnistaa ongelmia ja kompromissikohtia liittyen päästöjen ja muiden vaikutusten kokonaisvaltaiseen hallintaan,
- esitellä menetelmiä ristikkäisvaikutusten käsittelyä varten,
- osoittaa mitä mahdollisuuksia ympäristöhaittojen ja -hyötyjen kokonaisvaltaisella tarkastelulla on paikallisessa ympäristölupamenettelyssä, sekä,
- kuvailla teollisen toiminnan ympäristönsuojeluun liittyvien toimenpiteiden kustannuksia ja niiden arviointiin käytettäviä taloudellisia menetelmiä.

Tarkastelutapa ja menetelmät

Näkökulman merkitys

Viranomaiset ja poliitikot määrittelevät ympäristöpoliittisia tavoitteita ja yritykset pyrkivät toteuttamaan niitä. Tällöin on hyödyllistä erottaa toisistaan myös yksityisen ja julkisen talouden toimijan näkökulmat, jotka eivät aina välttämättä kohtaa. Julkisen vallan toivomat investoinnit eivät aina ole yksityisen yrityksen kannalta riittävän houkuttelevia. Toisaalta investointi saattaa olla yksityiselle yritykselle taloudellisesti kannattava, vaikka se ei olisi yhteiskunnallisesti toivottava. Ympäristönsuojelutoimenpiteet ovat usein sellaisia, että niistä aiheutuvat kustannukset voidaan kohdentaa päästölähteelle, mutta suojelusta aiheutuvaa hyötyä ei voida rajata.

Haitallisia aineita ympäristöön päästävän laitoksen toimintaan vaadittava ympäristölupa on ympäristöpoliittisen päätöksenteon tulos. Luvan myöntämistä edeltäviin vaiheisiin liittyy eri sidosryhmien kuulemista. BAT-teknologioiden tuottamien ristikkäisvaikutusten vertailu ei ota huomioon pelkästään ympäristörajoitteita, vaan myös tarvittavien investointien taloudellisen toteuttamiskelpoisuuden. Taloudellisen toteutettavuuden ja ympäristövaatimusten välinen tasapaino voidaan saavuttaa monella tavalla. Esimerkiksi päästörajojen muuttaminen, siirtymäjakson pituuden määrittäminen sekä parempia ja edullisempia ympäristönsuojelutekniikoita koskevat T&K-ohjelmat voivat kaikki osaltaan auttaa tasapainon saavuttamisessa.

Ympäristöinvestointien luonne

Yleisellä tasolla voidaan sanoa, että ympäristöpoliittiset tavoitteet (niihin liittyvät lait ja asetukset) velvoittavat teollisuuslaitoksia vähentämään päästöjään. Tästä syystä monet niistä joutuvat investoimaan uuteen teknologiaan. Luvussa esitellään muutamia kustannuslaskennan menetelmiä ja käsitteitä, joita voidaan soveltaa ympäristöinvestointien arviointiin. Ympäristöinvestointien analyysi liittyy läheisesti ympäristölaskentatoimeen. Perinteisten investointien odotetaan tuottavan taloudellista hyötyä yritykselle, mutta ympäristöinvestoinneilta tämä vaatimus puuttuu. Kansallisella ja EU:n tasolla ympäristöteknologian käyttöönottoon ja kehittämiseen vaikuttavat uusien teknologioiden kysyntä, T&K toiminta, niistä aiheutuvat kustannukset sekä hallinnon tarjoamat kannustimet.

Todellisuudessa puhtaasti taloudellisin vaikuttein tehdyn investoinnin ja ympäristöinvestoinnin välille on vaikea tehdä eroa. Yhä useampi investointi sijoittuu näiden kahden ääripään välille. Esimerkiksi sopii ympäristöinvestointi, joka säästää energiaa ja sitä kautta pienentää kustannuksia. Investoinnin motiivien monitahoisuus vaikeuttaa kustannusten erillistä kohdentamista ympäristönsuojeluun. Ympäristöinvestointien kustannukset ovat vaatimusten myötä nousseet niin korkeiksi, että kustannuksia ei voida sijoittaa yleiskustannuksiin, vaan entistä tarkempi kohdentaminen on välttämätöntä.

Kustannuslaskennan menetelmiä ja käsitteitä

Raportissa tarkastellaan yrityksen omiin ympäristöinvestointeihin liittyvää kustannuslaskentaa. Yhteiskunnan näkökulmasta näistä investoinneista johtuvat kustannukset ovat ns. ”yksityisiä kustannuksia”. Elinkaarikustannuslaskenta ja ympäristöhaittojen ja -hyötyjen arvotus sisältävät yrityksen ulkopuolisia kustannuselementtejä. Tutkimuksessa päätettiin kuitenkin keskittyä yrityksen sisäisiin kustannuksiin. Ympäristölaskennan merkitys yrityksille on kasvamassa. Ympäristönsuojelutoimenpiteiden painopisteen siirtyessä piipunpääteknologiasta prosessi-integroituun teknologiaan on kustannusten kohdentamisesta tullut yhä haasteellisempaa.

Kustannuslaskentaa käsittelevä jakso on jaettu kahteen osaan sen mukaisesti, mihin investointisuunnittelun vaiheeseen yksittäiset menetelmät liittyvät:

1. Investoinnin arviointi – Kokonaiskustannusten arviointia (TCA) täydennetään nettonykyarvomenetelmällä (NPV), sekä esitellään vuositasolle laskettujen pääomakustannusten ja optioarvon käsitteet. Kustannus-tehokkuusanalyysiä on kuvailtu lyhyesti.
2. Kustannusten kohdennus (allokointi) – Toimintoanalyysin (ABC) esittely.

Esittelyjaksojen yhteydessä kuvaillaan lyhyesti sitä, miten yritykset voisivat soveltaa yllämainittuja menetelmiä.

Ympäristöä koskevien hyötyjen ja haittojen arviointi
IPPC:n määritelmän mukaan teollisen toimijan aiheuttamat ympäristöhaitat ovat seurausta veteen ja ilmaan kohdistuvista päästöistä, jätevirroista sekä energian ja raaka-aineiden käytöstä. Hyötyjen ja haittojen arviointi voidaan tehdä erottamalla toisistaan vaikutukset ekosysteemeille, ihmisten terveydelle, viihtyvyydelle ja muille ympäristön tarjoamille hyödyille. Toisaalta vaikutukset voidaan maantieteellisen vaikutuksensa mukaan jakaa paikallisiin, alueellisiin ja globaaleihin vaikutusluokkiin.

Teollisuuslaitoksen ympäristövaikutusten arvioinnissa määritellään vaiheittain seuraavat tekijät:

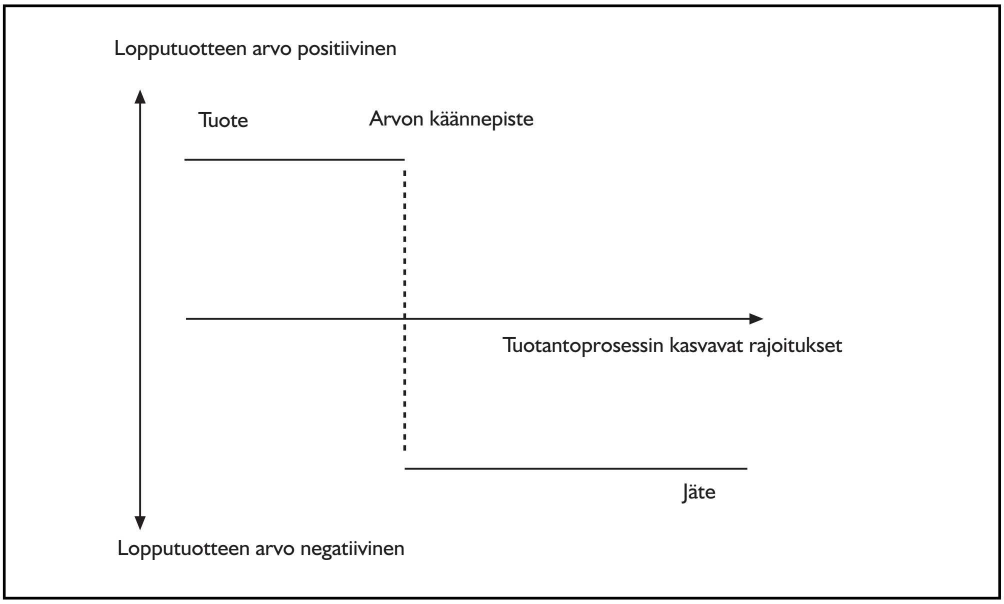
- haitallisista aineista aiheutuvien päästöjen laatu ja määrä, syntyvä jäte, melu ja lämpökuorma mukaan lukien tilapäiset vaihtelut ja häiriöt
- energiankäytön tehokkuus ja raaka-aineiden ympäristöominaisuudet
- haitallisten aineiden kulkeutuminen, hajoaminen, kerääntyminen ja muuntuminen sekä eliöiden, ihmisten ja rakenteiden altistuminen
- päästöjen, jätevirtojen sekä melu- ja lämpökuormien vaikutukset organismeille, populaatioille, habitaateille sekä ihmisten terveydelle ja viihtyvyydelle, sekä
- vaikutusten merkittävyys luonnon ekosysteemien, ihmisten ja yhteiskunnan kannalta.

Raportissa käsitellään myös erilaisia ympäristövaikutusten painotusmenetelmiä. Kaikkiin tällaisiin menetelmiin liittyy kuitenkin epävarmuuksia ja subjektiivisuutta. Ympäristövaikutusten monitahoisuudesta johtuen on arvioinnissa syytä noudattaa varovaisuutta.

Talous- ja ympäristönäkökohtien integrointi

Kokonaisvaltaisessa tarkastelussa on huomioitava sekä järkevän taloudenpidon että tavoiteltavan ympäristönsuojelun asettamat reunaehdot. Ristiriitoja näiden välillä esiintyy, mutta toisinaan toimenpiteet voivat vaikuttaa talouteen ja ympäristöön myös samansuuntaisesti.

Arvo on analyysimme keskeinen käsite. Pyrittäessä ratkaisemaan tiettyä nimettyä ongelmaa, voidaan tässä prosessissa joko luoda tai tuhota arvoa. On ole-



Kuva 40. Arvodiagrammi.

massa tietty risteyspiste ajassa, jossa esimerkiksi määrätyn tuotteen arvo muuttuu negatiiviseksi eli siitä tulee jätettä. Tätä voidaan kutsua ristikkäisvaikutusten ”käännepisteeksi” (value cross-over). Arvon käsitteeseen liitetään myös investoinnin sosiaalinen tai ympäristönsuojelullinen arvo. Arvon tarkastelua havainnollistetaan kuvan 40 avulla.

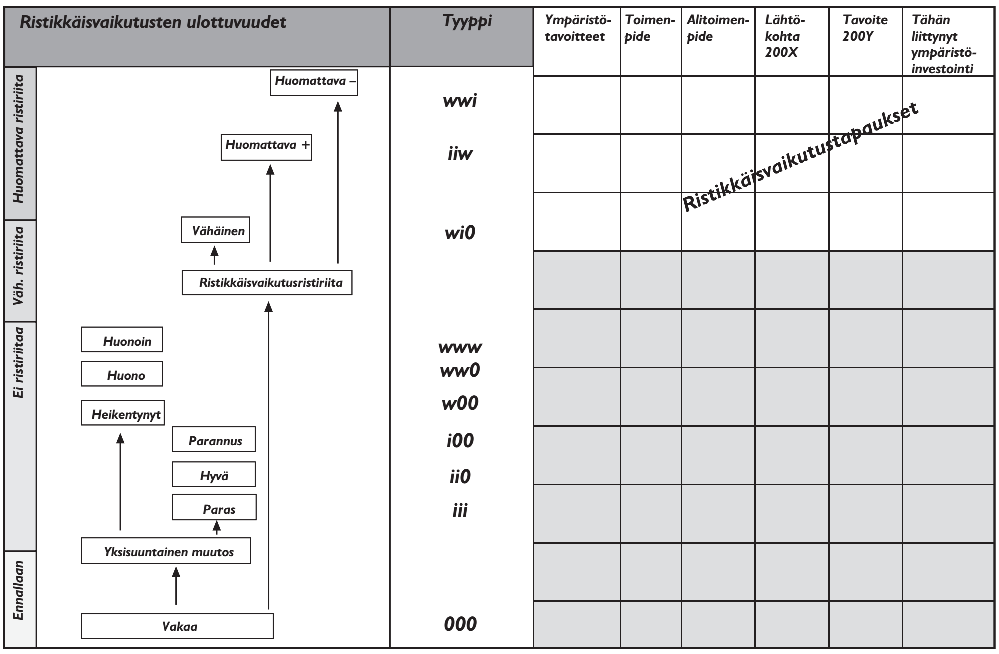
Suunnitelma menetelmien yhdistämiseksi

Ristikkäisvaikutusten tarkastelun tieteellinen pohja on yhdistettävä käytännöllisiin ratkaisuihin. Käytännön tapausten kohtaaminen ja käsittely auttavat ymmärtämään ristikkäisvaikutuksia paremmin. Tarkastelun kokonaisvaltaisuuden lisäämiseksi on kehitetty kolme periaatetta. Johtavana periaatteena on ns. ”Linssi-periaate” (the ”Lens Principle”) ja käytännöllisinä työkaluina toimivat ”Ristikkäisvaikutusten toimintataulukko” (the ”Cross-Media Action Table”) ja ”Näkökulmaluettelo” (the ”Perspective List”). ”Linssiperiaatteen” perusajatuksena on, mitä monimutkaisempi ja vakavampi ristikkäisvaikutusongelma, sitä useampia tarkastelunäkökulmia tarvitaan eli tulee käyttää useampia tarkastelumenetelmiä. ”Näkökulmaluettelo” on kokoelma suositeltuja yhdistelmiä tietyn tyyppisten tapausten analysointiin. Sikäli kun se on mahdollista, eri näkökulmat on myös nimetty. Ristikkäisvaikutusten toimintataulukkoa tarkastellaan yksityiskohtaisemmin kuvien 41 ja 42 avulla.

Ristikkäisvaikutusten toimintataulukko

Ristikkäisvaikutusten toimintataulukko sisältää vastaukset seuraaviin kysymyksiin:

- **Millainen ristikkäisvaikutus on kyseessä?**
  Ristikkäisvaikutusten laadun kuvaus ja vaikutusten luokitus.
- **Mikä on tavoitteena?**
  Ympäristönsuojelutavoitteet (määritetty tapauskohtaisesti)



Ristiriitojen tyyppien lyhenteet: w = huononee, i = paranee, o = ei muutosta alkuperäiseen tilanteeseen verrattuna

Kuva 41. Ristikkäisvaikutusten toimintataulukko (Cross media action table).

- **Mitä toimia tulisi suorittaa?**
  Tarvittavat ensisijaiset ja toissijaiset toimenpiteet (ympäristötavoitteiden saavuttamiseksi). Toimenpiteet saattavat sisältää näkökulmaluettelossa mainittuja menetelmiä.
- **Mitkä ovat mitattavat ympäristönsuojelun ja talouden tavoitteet?**
  Lähtötilanne ja saavutettava tulos (aikajanalla), joille asetettu selkeät mitattavat tavoitteet.
- **Mitä investointeja tarvitaan?**
  Tarpeelliset ympäristö- tai muut investoinnit.

Kuvassa 42 ristikkäisvaikutusten toimintataulukkoa on sovellettu yksittäisessä esimerkkitapauksessa.

Johdanto esimerkkitapauksiin

Monen ulottuvuuden ongelma
Tarkastelun kohteeksi sopivien ristikkäisvaikutusten määrä on melko suuri. Tutkimuksessa valitsemme ensin
- tarkasteltavat ulottuvuudet, ja sitten
- esimerkkiongelmat.

Tapaus 1: Ilma ja kiinteä jäte – sekä kustannus

Kysessä on puhdas ympäristöinvestointi, missä yrityksen on investoitava savukaasujen märkäpesuriin monipolttoainekattilan ilmaan kohdistuvien päästöjen puhdistamiseksi.

Päätöksentekotilanne
Päätöksentekotilannetta kuvataan sekä yrityksen että ympäristöviranomaisen näkökulmasta. Tapauksen yritys on keskikokoinen ja investointi on sille taloudellisesti pieni/keskikokoinen. Ensisijainen kannustin investoinnin tekemiseen on voimassaoleva lainsäädäntö. Muita yrityksen kannalta huomioon otettavia seikkoja ovat tarvittavien laitteiden hinta ja luotettavuus, muut mahdolliset kustannukset ja tapa, jolla yritys kykenee käsittelemään muodostuvaa jäteongelmaa.

On mahdollista, että yritys joutuu hakemaan muutosta ympäristölupaansa kaatopaikan vuoksi. Tärkein päätöksentekoon vaikuttava tekijä on viranomaisten kanta ilmansuojelua ja toisaalta jätteen käsittelyä kohtaan.

	Ristikkäisvaikutusten ristiriidat	Tyyppi	Ympäristötavoitteet	Toimenpide	Alitoimenpide	Lähtökohta 200X	Tavoite 200Y	Tähän liittynyt ympäristöinvestointi
HUOMATTAVA RISTIRIITA/NEGATIIVINEN	Happamoittavat päästöt (i) Päästöt vesiin (w) Jätteet (w)	iww	Vähentää happamoittavia päästöjä ilmaan, samalla säilyttäen ennallaan tai vähentäen kiinteiden jätteiden määrää ja päästöjä vesiin.	Savukaasupesurin asentaminen	Eri ympäristöelementteihin joutuvien päästöjen arviointi pesurin kanssa ja ilman pesuria, kustannusten laskenta, hyötyjen ja haittojen analysointi	SO_2 610 mg/m^3 HCl 50 mg/m^3 Hiukkaset 30 mg/m^3	Saada happamoittavat päästöt selvästi kansallisten tavoitearvojen alapuolelle	Savukaasupesuri ja sen tarvitsema kaatopaikka

Kuva 42. Ristikkäisvaikutusten toimintataulukko: Tapaus 1.

Edut ja haitat

+ SO_2-päästöt laskevat lähes 90 %
+ HCl-päästöt laskevat 80 %
– Kiinteän jätteen määrä kasvaa 5 m^3/pv
– Lisääntynyt energian ja raaka-aineiden kulutus
– Investointi on melko kallis ja käyttökustannukset ovat korkeat

Tapaus 2: Vesi ja kiinteä jäte – sekä kustannus

Tapauksen ongelma on yleinen ja liittyy useisiin jäteveden käsittelyprosesseihin. Näissä prosesseissa vettä saastuttavat aineet muunnetaan aina jollakin tavalla kiintoaineeksi. Kiintoaineesta muodostuu liete, joka viedään lopulta kaatopaikalle tai poltetaan.

Esimerkiksi on valittu kemikuumahierteen (chemithermomechanical pulp, CTMP) tuotanto, jossa veden kierto on lähes suljettu. Korkean kierrätysasteen vuoksi jätevesi sisältää paljon prosessissa puusta liuenneita orgaanisia aineita sekä kemikaaleista peräisin olevia epäorgaanisia aineita. Kahdesta potentiaalisesta jäteveden käsittelymenetelmästä ensimmäinen on perinteinen biologinen vedenpuhdistus. Toinen, vähemmän käytetty menetelmä on jäteveden haihduttaminen, ns. ”Zero Effluent Process”.

Esimerkkitehdas tuottaa CTMP:tä 400 kuiva-ainetonnia/pv ja suunnittelee investointia jompaan kumpaan edellä kuvatuista jäteveden käsittelymenetelmistä. Tapaustutkimuksessa vertaillaan investointivaihtoehtojen vaikutuksia.

Päätöksentekotilanne

Tapauksen yritys on kooltaan suuri, mutta investointi on kuitenkin sille taloudellisesti merkittävä ja on kyse uudesta teknologiasta. Tavoitteena on ensisijaisesti vähentää jäteveden aiheuttamaa kuormitusta. Muita päätökseen vaikuttavia tekijöitä ovat mm. laitteiden hinta ja toimittajan saamat suositukset. Yritys ottaa tietoisen riskin, mikäli se päättää investoida uuteen teknologiaan. Maankäytön suunnittelu vaikuttaa myös päätökseen.

Viranomaiset valvovat osaltaan laitetoimittajia ja keräävät kokemuksia uusien tekniikoiden käytöstä ja heille tarjoutuukin tässä yhteydessä myös mahdollisuus tukea ympäristöinnovaatioita.

Edut ja haitat

Esimerkkitapauksessa syntyy selvä ristiriitatilanne. On valittava halutaanko ensisijaisesti vähentää päästöjä veteen vai kiinteän jätteen määrää. Biologinen käsittely näyttäisi olevan kustannuksiltaan edullisempi vaihtoehto. Toisaalta, ympäristöinnovaation arvoa ei pitäisi aliarvioida varsinkaan kun kysessä on keskeinen ongelmakenttä (veden puhdistus).

Tapaus 3: Energia ja ilma/vesi/kiinteä jäte – sekä kustannus

Tapauksessa verrataan sähkön ja lämmön yhteistuotantoa (combined heat and power production, CHP) ja erillistuotantoa. Mikäli tarkastellaan saastuttavien päästöjen välttämisen kustannuksia suuren kokoluokan yhteistuotanto on eräs edullisimmista päästöjen vähentämiseen tarjolla olevista menetelmistä. Sen lisäetuna on myös korkea energiatehokkuus.

Tuotettaessa energiaa fossiilisista polttoaineista, laitoksilla, joilla on korkein energiatehokkkuus, on myös pienimmät päästöt. Tilanne kuitenkin monimutkaistuu, kun otetaan huomioon myös kustannukset. CHP-laitos muuntaa energiapanoksesta 40–70 % lämmöksi ja 20–45 % sähköksi riippuen järjestelmästä. Yhteistuotannon kilpailukyvyn kannalta on olennaista, että sähkön hinta on tarpeeksi korkea ja lämmölle on riittävä paikallinen kysyntä.

Tapaustutkimuksessa verrataan keskenään nykyistä sähkön ja lämmön yhteistuotantoon (CHP) perustuvaa vaihtoehtoa ja vastaavan sähkö/lämpömäärän tuottavaa erillistuotantovaihtoehtoa Jyväskylän alueellisessa energiajärjestelmässä. Erillistuotantoon perustuvassa vaihtoehdossa polttoainerakenne on sama kuin nykyisessä laitoksessa ja sähkö tuotetaan hiiltä käyttävässä lauhdevoimalassa.

Päätöksentekotilanne

Tapauksen yritys on suuri ja investointi on sekä strategisesti että taloudellisesti merkittävä. Ensisijainen vaikutin on nykyinen ja ennustettu sähkön hinta. Päätöksentekoprosessi on melko monimutkainen. Lämmön ja sähkön kysyntä on arvioitava. Polttoaineiden hinnat ja hintojen sekä saatavuuden tuleva kehitys on otettava huomioon. Yrityksen on myös muistettava, että CHP-järjestelmää on vaikea muuntaa muuhun käyttöön sen jälkeen kun se on rakennettu.

Viranomaisten tilanteen taustaksi voidaan mainita, että CHP:ta käsitellään Euroopassa vaihtelevin käytännöin. Brysselissä valmistellaan kannustimia CHP:hen kohdistuville investoinneille, mutta samanaikaisesti viranomaiset eri puolilla Eurooppaa tarttuvat kansallisen ja paikallisen tason kysymyksiin. Viranomaisen tulee päätöksenteossa ottaa huomioon energian tuotannon tavoitteet esim. tavoiteltava polttoainejakauma. Pohdittavana ovat myös paikallisen ja alueellisen tason ympäristöhallinnon vaikutusmahdollisuudet, kun investoinneilla on sekä paikallisia että alueellisia (ja laajempiakin) vaikutuksia.

Edut ja haitat

+ Korkeampi energiatehokkuus
+ Huomattavasti pienemmät päästöt
– Vaatimus, että on kysyntää sekä sähkölle että lämmölle
– Kannattamattomuus tietyillä polttoaineen ja energian hinnoilla

Sähkön ja lämmön yhteistuotannon edut liittyvät ilmapäästöjen pienenemiseen sekä polttoaineiden tehokkaaseen käyttöön. Kustannukset ja taloudellinen kannattavuus ovat sen sijaan erittäin tapauskohtaisia.

Tapaus 4: Energia, päästöt ja tuotteen/palvelun laatu

Tämä esimerkki on kuvaus tilanteesta, jossa tuotantoprosessiin liittyvällä muutoksella tähdätään myös päästöjen vähentämiseen tai muun ympäristöhyödyn saavuttamiseen. Muutokseen voi kuitenkin liittyä myös haittavaikutuksia, jotka ilmenevät tuotteen laadun heikkenemisenä, joidenkin muiden päästöjen lisääntymisenä tai prosessin energiatehokkuuden alenemisena. Myös kustannusvaikutukset ovat mahdollisia. Tarkoituksena on esittää tapaus, johon liittyy monenlaisia yhtaikaisia muutoksia.

Esimerkkitapauksessa paperitehdas tuottaa sanomalehtipaperia käyttäen raaka-aineenaan sekä puuhun että kierrätyspaperiin pohjautuvia massoja suhteessa 40 % TMP/ 60 % DIP. Tehtaan oletetaan käyttävän mekaanista tai biologista vedenpuhdistusta. Tehtaalla on monipolttokattila kuoren ja jäteveden käsittelyssä muodostuvan lietteen polttoa varten. Tehtaalla on kaksi TMP:tä käyttävää tuotantolinjaa, joista vanhempi pitää korvata uudella TMP tai DIP-linjalla. Tuotannon tulee säilyä entisellään eli 700 tonnia paperia/päivä.

Päätöksentekotilanne

Yritys on keskisuuri/suuri ja investointi on sille taloudellisesti merkittävä. Ensijainen vaikutin on raaka-aineen saatavuus ja hinta. Energian hinta ja kulutus saattaa myös keskeisesti vaikuttaa päätökseen. Yrityksen täytyy raaka-aineen saatavuuden ja hinnan lisäksi ottaa huomioon markkinakysyntä ja asiakkaiden vaatimukset. Laitevalintoihin vaikuttavat lähinnä hinta, käyttökustannukset sekä luotettavuus.

Viranomaiset eivät päätä teollisuuslaitoksen prosessivalintoja, mutta merkittävän tuotannon muutoksen tai uuden kierrätyskuitulinjan käyttöönoton seurauksena lupaehtojen ajantasaisuus joudutaan tarkistamaan. Kierrätysraaka-aineen käyttö sinänsä on perusteltavissa. Viranomaiset saattavat lisäksi joutua ottamaan kantaa kuljetusten lisääntymisen aiheuttamiin ympäristövaikutuksiin.

Edut ja haitat

Jos tehdas valitsee kierrätyskuidun lisäämisen TMP:n sijasta (20/80 vaihtoehto)

+ BOD_5 (biologinen hapenkulutus) laskee noin 10 %, COD (kemiallinen hapenkulutus) 12 % ja TSS (kiintoaineen määrä) 12 %.
+ Sähkön (oman tuotannon ja ostosähkön) tuotantoon tarvittavien polttoaineiden tarve vähenee 20 %
– Jäteveden määrä kasvaa 20 %
– Höyryn tuotantoon tarvittavien ostopolttoaineiden tarve kasvaa 20 %.
– Kiinteän jätteen määrä kasvaa melkein 10 %
– Siistauslietteen ja kiinteiden jätteiden lisäyksestä johtuen käsittelykulut kasvavat

Raaka-ainejakauman muuttaminen muuttaa paperin laatua tavalla tai toisella. Muutosten vaikutukset asiakkaalle ja asiakkaan odotukset on arvioitava huolellisesti.

Tutkimuksen johtopäätökset

Menetelmien arviointia

Yritysten ratkaistaviksi tulevat toiminnan ympäristövaikutukset ovat usein luonteeltaan monitahoisia. Tarkastelumenetelmien valinta on aina suoritettava tapauskohtaisesti mahdolliset epävarmuustekijät huomioon ottaen. Yritysten ja viranomaisten on tehtävä päätöksiä saatavilla olevan tiedon perusteella. Ympäristöinvestointeihin ja esimerkiksi yrityksen innnovaatiotoimintaan liittyy usein eri sidosryhmien intressejä, jotka täytyy selvittää ja ottaa huomioon.

Menetelmien valintaan liityvät kysymykset voidaan tiivistää esimerkiksi seuraavasti:

- Onko esiteltyjen kaltaisten menetelmien käytölle tarvetta? **Kyllä** – ilman niitä ympäristövaikusten arvioinnilta puuttuvat tieteelliset perusteet.
- Onko olemassa yhtä tiettyä menetelmää, joka voitaisiin valita ensijaisesti sovellettavaksi menetelmäksi? **Ehdottomasti ei.** Menetelmät nostavat esille asioiden eri puolia ja olisi suorastaan vaarallista käyttää niitä yksinään, silloin niiden heikkoudet jäisivät helposti liian vähälle huomiolle.
- Jos voimme käyttää vain yhtä menetelmää, minkä valitsisimme? **Vastaus riippuu täysin tilanteesta.** Menetelmän valinta on kiinni tutkimuksen tavoitteista ja tarkasteltavan tapauksen yksityiskohdista.
- Entä silloin kun on huolellisesti valittu tietty menetelmä (tai joukko useita eri menetelmiä), mikä on olennaista? **Kyseessä olevan menetelmän heikkouksien ja niiden seurauksien tiedostaminen ja esille tuominen.**

Ristikkäisvaikutusten luonteesta

Keskustelu ristikkäisvaikutuksista voidaan tulkita pyrkimykseksi saavuttaa hyvä ympäristönsuojelun taso siten, että ilmaan, veteen ja maaperään kohdistuvien päästöjen, korkean energiatehokkuuden sekä raaka-aineiden harkitun käytön välillä vallitsee paras mahdollinen tasapaino. Erilaisten ympäristö- ja terveysvaikutusten yhdennetyssä arvioinnissa on löydettävä kompromissi erilaisten häiriöiden esim. otsonikadon, happamoitumisen, otsonin muodostumisen, vesistöjen rehevöitymisen, ekotoksisuuden, sekä toisaalta luonnon monimuotoisuuden (biodiversiteetin), ihmisten terveyden ja viihtyvyyden välille. Tehtävät valinnat ja niiden tueksi esitetyt väitteet perustuvat paitsi tieteellisiin todisteisiin, myös päätöksentekijöiden arvoihin. Eräs arvoarvostelmien perusominaisuus on aikasidonnaisuus eli kulloinkin muodissa olevat painotukset vaikuttavat päätöksentekoon. Tämän takia ei ole käytettävissä mitään tiettyä laskusääntöä tai metodologiaa, joka voisi tuottaa objektiivisen tai oikean ratkaisun ristikkäisvaikutukseen liittyviin ongelmiin.

Esimerkeistä opittua

- Mitään menetelmää ei tule noudattaa orjallisesti. Ristikkäisvaikutuksiin sisältyvän vaihtokaupan punnitsemisessa on syytä soveltaa käytännöllistä realismia.
- Ympäristöinnovaatio voi tuottaa yritykselle myös aineetonta hyötyä, mikä saattaa myöhemmin koitua myös taloudelliseksi eduksi (esim. edelläkävijän maine). Viranomaisilla on tilaisuus pohtia rooliaan yleishyödyllisten innovaatioiden edistämisessä.
- Kansallisten ja paikallisten tarpeiden välinen tasapainottelu on haastavaa. Ympäristölle hyödylliseen investointiin voi liittyä monimutkaisia taloudellisia muuttujia. Sähkön ja lämmön yhteistuotannon tapauksessa yrityksen on nojattava ennusteisiin lämmön ja sähkön kysynnän ja hintojen kehityksestä pitkällä aikavälillä.
- Joskus investointiratkaisuun liittyy vaikeita ristiriitoja laadun, talouden sekä ympäristönsuojelun välillä. Tällöin on erityisen tärkeää muistaa tapauksen ainutlaatuisuus ja olla soveltamatta siihen liian yksinkertaistavaa menetelmää. Laadun suhteen on muistettava, että ääritapauksessa huonolaatuisesta tuotteesta tulee suoraan jätettä.

Päätelmät

Euroopan Komission läheisyysperiaate ”päätökset tulee tehdä alimmalla mahdollisella soveltuvalla tasolla” pätee myös ympäristönsuojelun ristikkäisvaikutusten tapauksessa. Paikalliset ristikkäisvaikutukset ja Euroopan tasolla ilmenevät ristikkäisvaikutukset ovat usein seurausta erilaisista kansallisista ympäristöpoliittisista tavoitteista. Paikallisen vaikutuksen tapauksessa täytyy voida ottaa huomioon paikalliset olosuhteet pitäen samalla kuitenkin laajempikin vaikutusalue mielessä. Päätöksenteon liiallisella keskittämisellä ja asioiden yleistämisellä voi olla vakavia haittavaikutuksia. Tutkimuksen tason ja tämänhetkisen tiedon saatavuuden huomioon ottaen ei yleistävien, teoreettisten laskelmien pohjalta ole syytä tehdä liian pitkälle meneviä johtopäätöksiä.

Ympäristöongelmat siirtyvät ulottuvuudesta toiseen ja muuttavat muotoaan jatkuvasti, mutta niiden ratkaisemiseksi tarvittava tieto voidaan toistaa. **Ehdotamme arvioitavaksi ajatusta ristikkäisvaikutusten ratkaisemisesta kerättävien tapaustutkimusten kokoamisesta Euroopan laajuiseksi tietokannaksi.**

Acronyms

a = Year
ABC = Activity Based Costing
ABM = Aversive Behaviour Method
ADt = Air dry ton
BAT = Best Available Techniques
BOD = Biological Oxygen Demand
CBA = Cost-benefit Assessment
CH_4 = Methane
CHP = Combined Heat and Power Production
CO_2 = Carbon Dioxide
COD = Chemical Oxygen Demand
CTMP = Chemithermomechanical Pulp
CVM = Contingent Valuation Method
d = Day
DIP = De-inked Pulp
ECF = Elemental Chlorine-free Pulp
EIA = Environmental Impact Assessment
€ = Euro
g = Gram
Gg = Giga gram
GDP = Gross Domestic Product
GHG = Greenhouse Gases
GWh = Giga Watt hour (10^6 kWh)
HCl = Hydrochloric Acid
HPM = Hedonic Pricing Method
IPM = Impact Pathway Method
IPPC = Integrated Pollution Prevention and Control
km = Kilometres
kWh = Kilowatt hour
LCA = Life Cycle Assessment
m^3 = Cubic Metre
MCA = Multi-criteria Analysis
mg = Milligram (10^{-4} g)
MJ = Mega Joule (10^6 J)
MW = Mega Watt
N-nutrient = Nitrogen Nutrient
NO_x = Nitrogen Oxides
N_2O = Nitrous Oxide
NPV = Net Present Value
P-nutrient = Phosphorus Nutrient
pH = Measure of acidity
RCF = Recycled Fibre
ROI = Return on Investment
SC = Supercalendered
SO_2 = Sulphur Dioxide
t = Ton
TCA = Total Cost Assessment
TCF = Totally Chlorine-free Pulp
TJ = Tera Joule (10^{12} J)
TMP = Thermomechanical Pulp
TSP = Total Suspended Particles
TSS = Total Suspended Solids

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Appendix 1. Life cycle assessment approach

Life cycle assessment (LCA) methodology has been standardised in EN ISO 14040–14043 series. The phases of a life cycle assessment are shown in Figure 1.

In defining the scope of an LCA study, a clear statement on the specification of the functions (performance characteristics) of the product shall be made. The functional unit defines the quantification of these identified functions.

Inventory analysis involves data collection and calculation procedures to quantify relevant inputs and outputs of a product system. These inputs and outputs may include the use of resources and releases to air, water and soil associated with the system. Interpretations may be drawn from these data, depending on the goals and scope of the LCA.

The impact assessment phase of LCA is aimed at evaluating the significance of potential environmental impacts using the results of the life cycle inventory analysis. In general, this process involves associating inventory data with specific environmental impacts and attempting to understand those impacts. The level of detail, choice of impacts evaluated and methodologies used depend on the goal and scope of the study.

The impact assessment phase may include elements such as:

- assigning of inventory data to *impact categories – classification*;
- modelling of inventory data within impact categories – *characterisation*
- possibly aggregating the results in very specific cases and only when meaningful – *weighting*

The methodological and scientific framework for impact assessment is still being developed. Models for impact categories are in different stages of development and there are no commonly accepted methodologies for consistently and accurately associating inventory data with specific potential environmental impacts.

The value of the impact category indicator can be calculated as follows:

$$I_{\mathrm{i}}(a) = \sum_{j=1}^{m} \mathrm{Load}_j\,(\mathrm{a})\,\mathrm{C}_{i,j}$$

$I_i(a)$ = value of the impact category indicator in an impact category i caused by a product system a,

$\mathrm{Load}_j\,(a)$ = emissions or other quantitative value of a polluting or stressing factor j,

$\mathrm{C}_{i,j}$ = characterization (or equivalency) factort of stressor j in connection with impact category i.

For global impact categories the characterisation factors are based on the recommendations of international organisations (Intergovernmental Panel on Climate Change, World Meteorological Organisation). The picture is not as clear for the other characterisation factors and there is an ongoing international work to further elaborate the factors.

Instead of general characterisation factors, which do not take into account the differences in the receiving environment, the modelling of more realistic impacts has recently gained more support. One approach to solve the problem is to elaborate emission specific characterisation factors $\mathrm{C}_{\mathrm{i,j}}(\mathrm{a})$ instead of general characterisation factors (Seppälä 1997, 1999). As an example of the need for the correction of the general characterisation factor for eutrophication one can argue that only a certain portion of total nitrogen released into a river are transported into nitrogen

LIFE CYCLE ASSESSMENT FRAMEWORK

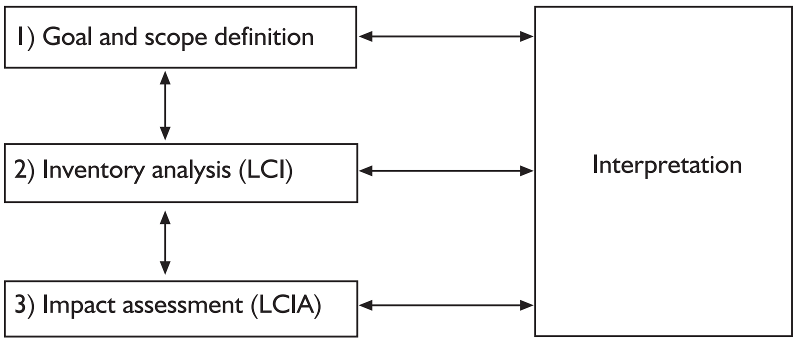

Figure 1. Phases of a life cycle assessment.

sensitive waters and out of that nitrogen only a certain portion is bio-available. i.e. actually causing eutrophication. The emission specific characterisation factors for acidification, troposheric ozone formation and eutrophication in Finland have been elaborated to take into account the transportation and effectiveness of the emitted component in a specific receiving environment (Seppälä 1997, 1999).

Seppälä, J. & Jouttijärvi, T. (Eds.) 1997. Forest industry and the environment (In Finnish with an English summary); The Finnish Environment 89; Helsinki: Finnish Environment Institute.

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Appendix 2. Public goods and environmental policies

The fact that public authorities intervene by means of regulations and taxes indicates that environmental qualities have ever more a public good character. In this appendix we explain in brief what the implications are of that acknowledgement.

Public goods are characterised by:

- non divisibility in production (it comes in big chunks)
- non excludability of consumers (separate units of consumption and/or consumers are hard to distinguish)

Pure public goods and free goods

If both above-mentioned characteristics apply, it is regarded as a pure public good, for which no prices or some kind of charge by amount of use can be applied, nor can it be delivered in small portions, meaning that the entire facility has to be produced at once in its entirety.

If the availability of a public good comes at zero cost, it is also a free good, implying that it is inexhaustible (not scarce). Some natural resources, e.g. the air, could be regarded as examples of free goods. Environmental damage often means that not the free good as such disappears, but that some of its functions are deteriorating. A topical example is the world climate system. To safeguard the sustenance of its service at a quality level which is acceptable for humanity, investments have to be made. Therefore the world climate is in a transition stage of becoming a public good. The alternative, pretending it still to be a free good, would incur tremendous cost in the long run. This provides the rationale to require various sectors to invest in abatement. Even if this would mean that commercial setbacks cannot be compensated entirely, it can be justified by the much larger cost for society at large. This also illustrates the dilemmas in policy implementation.

Similar considerations could be given to other large scale, often global, problems such as the depletion of ozone layer, acidification, biodiversity and, eutrophication. In all cases these are issues where originally free goods, like the air, fresh water, the sea, need to be redefined or at least some of their functions need re-labelling as public goods. Once this is done, there is a basis to demand charges or to impose physical limits.

Summarising, we can say that in the case of free goods no market mechanism is necessary, since there is no scarcity. For public goods, the problem is that on the one hand scarcity is relevant, but the standard working of a market is not feasible. So, the notion of a cost is to be communicated to the users (the public) by means of policy intervention in order not to violate the scarcity boundaries. The decision on the volume of provision and the level of charge is to be made in a different way than in a conventional market. On the basis of public discourse and accountable decision making a desired sustainable quality level has to be specified, usually balancing between reasonable quality and manageable cost, including tests on the relation between the level of charge and the demand for the service under agreed scarcity boundary conditions. This BAT cross media study is an example of an element in such a discourse.

Policy instruments for environmental qualities declared as public goods

Once the scarce aspects of an originally free good have been acknowledged and hence the aspect is defined as a public good the next step is to select instruments to communicate the scarcity. Unlike public goods such as national defence, the choice in service levels of many natural resources is limited, the idea is rather that the service level should not deteriorate beyond a certain level since that would cause intolerable costs. In the case of the world climate the discussion is in fact on how much deterioration can still be allowed, and how should the resulting space for use of the air for emissions be allocated. This results in the following questions:

- how much emission capacity is left for the whole world up to e.g. 2100 (what are concentrations of greenhouse gases in the atmosphere that the changes remain within manageable limits – in practice 450 vs. 550 ppm trajectories)
- how to allocate the emission capacity to entities; given prevailing international law, these entities are countries (assigned amounts per country for the first commitment period 2008–2012 in the Kyoto Protocol)
- how to ensure that economic activities in a country do not emit more in a certain time period than is agreed on according to capacity allocation (the national programmes of Annex 1 countries and international emission trade)

The first question is less problematic since a very large majority of politicians and scientists is now convinced that the figures of the IPCC are accurate. The choice of trajectory has to be made however within this decade.

The second point is temporarily solved with specifications for the so-called first commitment period (the Kyoto Protocol). However, once the trajectory is agreed on, this question will return and touches profound issues regarding how the richer countries allow the poorer countries to develop, which irrevocably implies that initially richer countries have to do more reduction effort. Poorer countries have to assess when they need to step in to a commitment process in order to balance equity with feasibility of achieving a global target. From that point onwards also committed developing countries will have to deal with the management of redistribution of benefits and costs.

A lot of economic literature focuses in fact on third issue, namely what are the right instruments and what is the right mix given the specified commitments.

Environmental effects in market environments – pricing or standards

The previous sections gave examples of environmental problems arising from the very fundamental transition of a free good towards a public good. Another category of environmental issues is borne in activities, carried out in a market, but affecting activities either in other markets or outside markets in a way that is not automatically traceable via market information. These are so-called external effects or spill-over effects, meaning that the effects concern companies or people outside the market where the effect is created. Since, in this case there is usually a limited number of (point) sources public intervention can be of a different nature than in the examples in the previous section. The recommendable approach is so-called internalisation of the external cost[1]. In reference to the BAT cross media study one can say that by the obligation to invest in order to comply to regulation the external costs are internalised. Also an emission tax is a way to internalise external cost.

Public intervention preferably focuses on ensuring that the cost are internalised in the production cost. Although in the case of external effects there is more information about the source and about the ones affected, that leaves still sufficient space for research questions. First, the assessment of the effects, both physically and in terms of valuation can be quite difficult. Secondly, there are several ways to assess what is the optimal solution, notably with regard to the question whether the solution should be source oriented or focus on the impact side.

1. In principle the global problems such as climate change are external effects as well, but the scale both in terms of space and time is so large that these global problems are a category in their own right. Nevertheless, also here internalisation of the external cost is for example possible in energy conversion as soon as some price (charge) is attached to for example emissions.

Time plays an important role regarding solutions. In the short run it may be practically only feasible to do something at the impact side, as source oriented solutions tend to take more time, due to R&D requirements. In welfare theory the impact versus source oriented solutions are represented by compensating variation versus the equivalence variation, meaning what is cheaper for society – paying the affected a sum of money, equal to their valuation of the damage done (or implementing a measure that reduces the damage appreciably and compensate the remaining damage) or requiring investments at the source in order to eliminate the problem (perhaps involving subsidies e.g. in order to prevent bankruptcy of the companies involved).

Experiences in the past two decades demonstrate that problems with polluting discharges in water have often been effectively reduced by applying effluent charges in combination with permits and norms. Traffic noise containment on the other hand seems to depend much more on norms, e.g. in zoning in urban areas and in building codes.

Compensation of the affected is not without criticism, as there are – at least in theory – risks for overcompensation. For example, in the case of noise effects real estate prices are usually lower than comparable real estate prices without noise hazards. If the noise problem exists already a long time, it gets probable that many households and companies that bought the affected real estate, valued that the lowered cost of the real estate compensates them sufficiently for the anticipated damage of the noise. The problem is, however, that the a priori imagined seriousness of the noise hazard can significantly differ from the actual valuation of the hazard once it is experienced daily. This is an example of incomplete information which – in the case of noise – is hard to alleviate. Furthermore, noise levels may increase over time, while a part of the affected may have moved into the area in a period with lower noise levels. Another aspect is that an area that for example otherwise would be very attractive for residential area loses that attractiveness and cannot develop the remaining potential of that function, forcing potential dwellers to second best solutions. In case of traffic noise this can lead to a self-reinforcing cycle, in case second best solutions increase car (and bus) commuting.

In case source oriented solutions are not significantly more expensive than impact oriented solutions, while the sources are well identifiable and not tremendously exposed to foreign competition or a substitute product from another market, and technical development depends on a third party, it is generally better to impose a norm and allow involved companies to adapt to that norm within a certain time period. Road transport (vehicles, pavement qualities) is a good example for this approach. Attaching a price (i.e. a decibel tax) may only cause extra cost for car users, without much actual technical achievements. If technical development can be steered more or less by the parties representing the pollution source itself, taxation will become a more effective instrument (provided that existing taxes are not much reducing the marginal effect of the new tax). If foreign competition is significant, a subsidy could be justified, perhaps only for R&D. In case of good domestic alternatives, subsidies are less obvious, though in case of sizeable local or regional socioeconomic impacts a restructuring programme may be called for.

Summarising, we can say that environmental external effects, when born in market activities can often be internalised by attaching a price to the effect. The attachment of a price implies that either the affected is compensated for the hazard (including hazard neutralising measures) or the source diminishes the generation of the effect by investing in better production methods. If the source has not much discretion over the technologies used, e.g. in case of private car owners, while foreign competition is insignificant, a norm can be applied.

Documentation page

Publisher	Finnish Environment Institute	Date January 2002
Author(s)	Petri Vasara, Kimmo Silvo, Pia Nilsson, Laura Peuhkuri, Adriaan Perrels	
Title of publication	Evaluation of environmental cross-media and economic aspects in industry – Finnish BAT expert case study	
Parts of publication/ other project publications		
Abstract	The report deals with environmental cross media and economic aspects related to industrial installations. Emphasis is placed on the assessment of environmental cross media conflicts. The study is the Finnish contribution to the corresponding EU reference document preparation carried out in accordance with the IPPC Directive. It also adds to the knowledge basis of integrated industrial environmental permitting in Finland. Various approaches and methods are highlighted and discussed and a methodological framework for combined environmental and economic evaluation is presented. The chosen methodological approach is demonstrated with four cases from pulp and paper industry and energy production. The dimensions of trade-offs and possible conflicts cover air, water, soil, energy, time, product quality and costs. The economic methods are defined for investment appraisal and cost allocation. The selection of the analysis is proposed to be dependent on the complexity of the cross media problems. The use of "cross media action table" and "perspective list" is highlighted in the cases chosen. The conclusions point out that there is a need for several methods to deal with cross media and economic issues. The choice of methodology depends on the case specific situation. Being aware of, discussing and considering the particular weaknesses of the methods chosen is essential. Rigid and standardised methodology on sector level is not endorsed. An idea to establish a European information base on actual cases of solved cross media problems is proposed.	
Keywords	industry, evaluation, environment, cross-media aspects, economy	
Publication series and number	The Finnish Environment 528	
Theme of publication	Environmental protection	
Project name and number, if any		
Financier/ commissioner	Ministry of the Environment, Finnish Environment Institute, Finnish Forest Industries Federation, Finergy	
Project organization	Jaakko Pöyry Consulting Oy, Finnish Environment Institute, Government Institute for Economic Research, Finnish Forest Industries Federation, Finergy, Ministry of Trade and Industry	
	ISSN 1238-7312	ISBN 952-11-1042-2, 952-11-1043-0 PDF
	No. of pages 115	Language english
	Restrictions For public use	Price 14,63 €, 87,00 mk
For sale at/ distributor	Edita LTD, tel 358 9 566022, telefax 358 9 566 0380 e-mail: asiakaspalvelu@edita.fi, www-server: http://www.edita.fi/netmarket	
Financier of publication	Finnish Environment Institute P.O. Box 140, FIN-00251 Helsinki, Finland	
Printing place and year	Edita Ltd, Helsinki 2002	

Kuvailulehti

Julkaisija	Suomen ympäristökeskus	Julkaisuaika Tammikuu 2002
Tekijä(t)	Petri Vasara, Kimmo Silvo, Pia Nilsson, Laura Peuhkuri, Adriaan Perrels	
Julkaisun nimi	Ympäristönsuojelun ristikkäisvaikutusten ja taloudellisten näkökohtien arviointi teollisuudessa – Suomen BAT-asiantuntijoiden tapaustutkimus	
Julkaisun osat/ muut saman projektin tuottamat julkaisut		
Tiivistelmä	Työssä käsitellään teollisiin toimintoihin liittyviä ympäristöllisiä ristikkäisvaikutuksia ja taloudellisia näkökohtia. Pääpaino on ympäristöllisten ristikkäisvaikutusten ongelmatiikassa. Raportti on Suomen panos vastaavan EU:n IPPC direktiivin mukaisen vertailuasiakirjan valmisteluun. Samalla työ antaa näkökulmia yhtenäisen ympäristölupamenettelyn edellyttämiin menettelyihin Suomessa. Raportissa kuvataan useita menetelmiä ja menettelytapoja sekä luodaan metodinen viitekehys ympäristöllisten ja taloudellisten näkökohtien yhtenäiselle käsittelylle. Menetelmärunkoa sovelletaan neljään esimerkkitapaukseen metsäteollisuudesta ja energian tuotannosta. Tarkastellut ulottuvuudet käsittävät ilman, veden, maaperän, energian, ajan, tuotteen laadun ja kustannukset. Kustannuslaskennan menetelmiä investointien arvioinnissa ja kustannusten kohdennuksessa kuvataan. Analyysien valinta ehdotetaan tehtäväksi ristikkäisvaikutusongelman monimutkaisuuden perusteella. Esimerkkitapausten pohjalta esitellään ”ristikkäisvaikutusten toimintataulukon” ja ”näkökulmaluettelon” soveltamista. Johtopäätöksenä todetaan, että ristikkäisvaikutusten ja taloudellisten näkökohtien käsittelyyn tarvitaan useita menetelmiä. Metodiikka joudutaan määrittelemään tapauskohtaisesti. Menetelmien puutteiden ja heikkouksien käsittely on tärkeää. Toimialakohtaisesti sovellettavaa kaavamaista ja standardisoitua metodiikkaa ei pidetä tarkoituksenmukaisena. Työssä ehdotetaan perustettavaksi eurooppalainen tietokanta ratkaistuista ristikkäisvaikutuksia sisältävistä esimerkkitapauksista.	
Asiasanat	teollisuus, arviointi, ympäristö, ristikkäisvaikutukset, talous	
Julkaisusarjan nimi ja numero	Suomen ympäristö 528	
Julkaisun teema	Ympäristönsuojelu	
Projektihankkeen nimi ja projektinumero		
Rahoittaja/ toimeksiantaja	Ympäristöministeriö, Suomen ympäristökeskus, Metsäteollisuus ry, Finergy	
Projektiryhmään kuuluvat organisaatiot	Jaakko Pöyry Consulting Oy, Suomen ympäristökeskus, Valtion taloudellinen tutkimuskeskus, Metsäteollisuus ry, Finergy, Kauppa- ja teollisuusministeriö	
	ISSN 1238-7312	ISBN 952-11-1042-2, 952-11-1043-0 PDF
	Sivuja 115	Kieli englanti
	Luottamuksellisuus Julkinen	Hinta 14,63 €, 87,00 mk
Julkaisun myynti/ jakaja	Oy Edita Ab, Asiakaspalvelu, PL 800, 00043 Edita, puh. (09) 5660266, telefax (09) 566 0380 e-mail: asiakaspalvelu@edita.fi, www-server: http://www.edita.fi/netmarket	
Julkaisun kustantaja	Suomen ympäristökeskus PL140, 00251 Helsinki	
Painopaikka ja -aika	Oy Edita Ab, Helsinki 2002	

Presentationsblad

Utgivare	Finlands miljöcentral		Datum Januari 2002
Författare	Petri Vasara, Kimmo Silvo, Pia Nilsson, Laura Peuhkuri, Adriaan Perrels		
Publikationens titel	Utvärderingen av miljö cross media och ekonomiska aspekter i industrin – Finsk BAT-expert fallundersökning		
Publikationens delar/ andra publikationer inom samma project			
Sammandrag	I rapporten behandlas cross media och ekonomiska aspekter i industriella aktiviteter, med betoning på problematiken kring miljö cross media effekter. Rapporten är Finlands bidrag till bearbetningen av motsavarande EU referensdokument under IPPC direktivet. Arbetet bidrar även till att förstärka kunskapsbasisen på metoderna av den integrerade miljötillståndsprövningen i Finland. I rapporten skildras flera metoder och handlingssätt och en metodisk ram för en förenad behandling av miljö och ekonomiska aspekter presenteras. Metodiken tillämpas på fyra exempel från skogsindustrin och energiproduktionen. De behandlade dimensionerna omfattar luft, vatten, jordmån, energi, tid, produkt kvalitet och kostnader. De ekonomiska metoderna för investeringsutvärdering och kostnadsallokering beskrivs. I rapporten föreslås att den använda analysen väljs på basis av hur komplicerad cross media problemet verkligen är. I exemplen demonstreras tillämpningen av ”cross media verksamhetstabellen” och ”perspektiv förteckningen”. Som slutsats konstateras, att det behövs flera olika metoder för att behandla miljö cross media och ekonomiska aspekter. Metodiken är beroende av de ifrågavarande fallen. Det är viktigt, att de utvalda metodernas brister och svagheter diskuteras och utvärderas. En utveckling av en standardiserad och styv metodik på sektor nivå inom EU anses inte ändamålsenlig. Däremot föreslås att en europeisk databas etableras för fall där cross media konflikter har behandlats.		
Nyckelord	industri, utvärdering, miljö, cross-media aspekter, ekonomi		
Publikationsserie och nummer	Miljön i Finland 528		
Publicationens tema	Miljövård		
Projektets namn och nummer			
Finansiär/ uppdragsgivare	Miljöministeriet, Finlands mijöcentral, Skogsindustrin rf, Finergy		
Organisationer i projektgruppen	Jaakko Pöyry Consulting Oy, Finlands miljöcentral, Statens ekonomiska forskningscentral, Skogsindustrin rf, Finergy, Handels- och industriministeriet		
	ISSN 1238-7312	ISBN 952-11-1076-1, 952-11-1077-5 (PDF)	
	Sidantal 115	Språk finska	
	Offentlighet offentlig	Pris 14,63 €, 87,00 mk	
Beställningar/ districution	Edita Ab, Kundservice, PL 800, 00043 Edita, tel. (09) 5660266, telefax (09) 566 0380 e-mail: asiakaspalvelu@edita.fi, www-server: http://www.edita.fi/netmarket		
Förläggare	Finlands miljöcentral PB140, 00251 Helsingfors		
Tryckeri/ tryckningsort och -år	Edita Ab, Helsinki 2002		

The Finnish Environment

ENVIRONMENTAL PROTECTION

Evaluation of environmental cross-media and economic aspects in industry – Finnish BAT expert case study

The publication is available in the Internet:
http://www.vyh.fi/eng/orginfo/publica/electro/fe528/fe528.htm

ISBN 952-11-1042-2
ISBN 952-11-1043-0 (PDF)
ISSN 1238-7312

EDITA Ltd.
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Annankatu 44, phone (09) 566 0566

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